

National Aeronautics and Space Administration

2012 Annual Report | NASA Earth Science Applied Sciences Program



2012

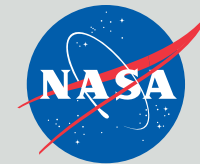
Annual Report

NASA Earth Science
Applied Sciences Program

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NASA Earth Science Applied Sciences Program

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Image credits: Utah State University/ForCaMF (forest disturbance map, p. 9), NOAA (ship and whale, p. 10), FEMA (levee monitoring, p. 13; hurricane destruction, p. 21; disaster preparation, p. 22; disaster responders, p. 38; blue shirt, p. 54; people standing at meeting, p. 78), CDWR (levee repair, p. 14), Ray Rivera/USFS (Chinook salmon, p. 28), NIH (heat wave, p. 32), U.S. Department of Veterans Affairs (heat wave, p. 33), NASA GSFC SVS (Nile LDAS, p. 40), ForWarn (Atchafalaya flooding, p. 57), CAL FIRE (helicopter and firefighter, p. 82).

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Letter from the Director



Lawrence Friedl, Director, Applied Sciences Program

Welcome to the NASA Applied Sciences Program's 2012 Annual Report. The year was full of progress and results in applying Earth science data and models to improve decision making, productivity, and quality of life. The Program continues to promote novel applications, build capacity, and engage people in satellite mission planning. This report features some of our accomplishments in 2012.

A number of projects addressed major events and challenges. In response to Hurricane Sandy, a project employed data from *Suomi NPP* to identify areas without power. The information aided FEMA, USACE, and others to assess power restoration efforts, allocate resources, and distribute relief supplies more effectively. Based on another project, the U.S. Forest Service rolled out a NASA-developed carbon assessment tool to the National Forest System. Using *Landsat* data to create maps of forest disturbance, the tool helps forest managers monitor carbon stocks and make decisions on timber use, grassland management, and habitat conservation.

Several projects outside the public eye informed decision making and policy. Applying data from *Aqua*, *Terra*, and NASA's LIS system, a project involving the National Drought Mitigation Center characterized a "flash drought" in Alabama and its impact on corn yields. The project's results led to Alabama irrigation tax credit legislation passed in 2012. In partnership with CDC, a project integrated satellite-based environmental data sets into CDC's online WONDER information system, assisting health professionals to account for environmental risks and promote public health. Initiatives in Africa expanded the use of the CREST hydrological model and *TRMM* data to aid local authorities with farming practices, water management, and early warnings of floods.

The past year was noteworthy for awards. Inside this report are stories of a project that won awards for technology transfer and science delivery, a team that won a Wildlife Society award, and a DEVELOP mentor who won NASA's Exceptional Public Achievement Medal. You'll also learn that NASA gained a place in a GIS hall of fame.

We continued key initiatives and pursued new activities in 2012. We completed more socioeconomic impact analyses of our projects and hosted events on socioeconomic benefits of Earth observations. ARSET and DEVELOP had record-breaking years in participation and scope, and SERVIR launched a new website. We supported more climate risk workshops with NASA Centers on their climate adaptation planning. We initiated bimonthly program reviews and introduced associate program managers to further our engagement with project teams. We again sponsored an Ignite-style event at the American Geophysical Union annual meeting, and we launched a mobile app.

We want to thank Cassandra Nuñez, who was the AAAS Science & Technology Policy Fellow with Applied Sciences in 2011–2012, for her contributions. We also remember Greg Leptoukh and Rob Raskin, who passed away in 2012. Each of them supported broader efforts to make data readily accessible and usable to inform decisions.

On behalf of the Program, I want to thank our project teams and partners for their innovation, enthusiasm, commitment, and rigor in applying Earth observations for societal benefit.

Building on a very productive year, we're enthusiastic to continue demonstrating the value of Earth observations and eager to pursue new opportunities and effective ways to apply Earth science to serve society.

A handwritten signature in black ink that reads "Lawrence Friedl".

*The Applied Sciences Program is part of the Earth Science Division of the NASA Science Mission Directorate.
To learn more about the Applied Sciences Program, visit <http://AppliedSciences.NASA.gov>.*



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Definitions of some acronyms appear in the text; others appear in the acronym list on page 100.



Featured Projects

The Applied Sciences Program supports innovative applications of Earth observations and models to enhance decision making across industry, government, and civil society.

During 2012, the Program sponsored projects that improved the management of natural resources, informed the links between the environment and disease, bolstered wildlife conservation, supported tools for disaster response, and enhanced water management.

The following section contains a sampling of projects that reached important milestones and achieved results in 2012. These examples convey the significant socioeconomic benefits from the use of Earth observations—costs reduced, threats averted, ecosystems protected, economies supported, and quality of life improved.



Applying Research for Improved Forest Management



The U.S. Forest Service (USFS) manages the National Forest System (NFS) of more than 190 million acres, which is greater than a quarter of all forestland in the United States. Law, regulation, and internal policy require the agency to monitor carbon storage across national forests.

In 2012, USFS adopted an Earth Science Division (ESD)-developed carbon assessment tool, known as ForCaMF (Forest Carbon Management Framework), which uses satellite imagery as part of an approach to enhance forest management. In adopting it, USFS extended the tool from the pilot area to the entire NFS.

Forests help mitigate greenhouse gas emissions by absorbing and storing carbon in soil and trees. ForCaMF tracks forest conditions and provides information about the effects of forest disturbances, such as wildfires and timber harvests, on carbon storage. It creates fine-scale maps of biomass and disturbance maps using *Landsat* data products calibrated with field data from the USFS Forest Inventory and Analysis (FIA) program. Complementing FIA, ForCaMF provides information about the factors that influence carbon stocks over time—information that is critical to managers and is administratively required in the NFS planning process.

The ForCaMF maps combine with carbon dynamics programmed into the USFS Forest Vegetation Simulator to make historical and forward-looking carbon storage assessments. Building on the Forest Service's expertise with satellite remote sensing, USFS can utilize ForCaMF

for strategic carbon assessments at sub-regional and local scales, where most forest planning occurs.

“ForCaMF provides defensible estimates of recent stock changes for individual national forests,” said Jim Morrison, regional climate change coordinator, USFS Northern Region.



The origins of ForCaMF began with research sponsored by NASA's Carbon Cycle Science program (under ESD Research & Analysis). In later years, the project transitioned to ESD Applied Sciences for support of the

“ForCaMF is an important component of our applied carbon monitoring and assessment efforts.”

David Cleaves, U.S. Forest Service

application development and validation. In 2011, NASA and USFS collaboratively funded a pilot of ForCaMF for NFS lands in the Northern Rockies.

The success of the pilot led USFS in 2012 to fund the expansion of ForCaMF across the entire NFS, enhancing FIA operations and other long-standing management processes. ForCaMF map resources are the first of their kind to be produced consistently across the NFS. USFS is archiving these resources for other broad forest planning uses that might involve timber, water quality, or even habitats for endangered species.



Assessing and Managing

The FIA program produces detailed assessments of carbon stocks, and it is the source of information about U.S. forests in reports to the U.N. Framework Convention on Climate Change. With four decades of *Landsat* data available for disturbance maps, USFS can use ForCaMF to assess the effect of management and natural disturbance upon historical trends in carbon stocks in biomass and wood products. In other words, USFS can supplement the in-depth FIA information with a perspective on what is happening to carbon stocks and why.

The U.S. Forest Service adopted a NASA-developed forest carbon assessment tool, expanding its application to the entire National Forest System.

Landsat-based maps also contribute to the measurement of management-related emissions by quantifying, for example, forest road construction activity and pinpointing how far harvested timber must be hauled to move it from the forest to the mill. ForCaMF allows annual assessment of carbon stocks and fluxes as they respond to particular harvest strategies. Managers can enter alternative hypothetical scenarios into ForCaMF for comparison against each other and against actual disturbance

trends tracked by *Landsat*. This capacity is critical for establishing the net carbon benefit of one management approach over another.



ForCaMF is part of a larger USFS effort to monitor carbon stocks. Carbon assessment and stewardship is one element of the Climate Change Performance Scorecard, a program to help rate USFS management units in readiness and adaptability to climate change. As part of this, managers use baseline assessments of carbon stocks and the effects of disturbance and management activities on those stocks. In this way, ForCaMF can support their integration of carbon stewardship into overall resource management.

“ForCaMF is an important component of our applied carbon monitoring and assessment efforts,” said David Cleaves, USFS climate change advisor to the chief.

Sean Healey leads this project: seanhealey@fs.fed.us. To learn more visit, www.fs.fed.us/climatechange/advisor/scorecard/carbon-assessment-stewardship.html.



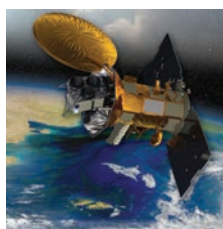
Map of forest disturbances, 1990–2011.

Advancing Marine Mammal and Protected Species Management



The U.S. Navy, Bureau of Ocean Energy Management, NOAA, and other entities use a Spatial Decision Support System (SDSS) in assessing the density and distribution of marine mammals, including whales, porpoises, and dolphins. Supporting efforts to reduce impacts on marine species from seismic surveys, naval exercises, oil drilling noise, and other human activities, a Program-funded project improved SDSS predictive models through new indices using satellite observations. In 2012, the U.S. Navy began using the modeling system for environmental impact compliance.

Developed to support marine mammal conservation, SDSS is a data management and statistical modeling system that allows users to visualize and explore predicted habitats for marine mammals around U.S. waters. Model results yield predictive maps for the likelihood of encounter from parameters such as depth, distance to shore, sea surface temperature (SST), and chlorophyll concentration. SDSS uses observations from the space-based sensors MODIS and AVHRR as well as data from NOAA surveys. As an interactive map server, the system enables examination of model outputs across multiple time scales and usable spatial formats.



An Applied Sciences project worked to improve cetacean population density estimates in SDSS. Together with partners at the U.S. Navy, Bureau of Ocean Energy Management (BOEM), and NOAA, the project team combined remote sensing data from *Aqua* and other satellites with *in situ* oceanographic measurements to create indices applicable to protected species in the northeast Pacific Ocean, northwest Atlantic Ocean, and Gulf of Mexico.

The team incorporated these indices into predictive models of species density, abundance, and habitat. SDSS also improved through the team's work to add a near real-time predictive capability based on the indices derived from available Earth observations. The team's habitat-based density models combine remote sensing data and ecologically significant variables.

Overall, the team enhanced the effectiveness of SDSS, increasing both the spatial and temporal perspective of

"We see this project as part of an ongoing effort to improve spatial density estimations, and NASA's Earth observations will play an important role in it."

James Michael Price, U.S. Bureau of Ocean Energy Management

models. SDSS now offers improved perspectives on past events and insights on the next month and next season.

"These analyses identify primary variables influencing marine mammal distribution, thereby providing the context for successful accommodation of whales and dolphins in marine spatial planning frameworks," said Tim Cole, aerial survey team lead at the NOAA Northeast Fisheries Science Center.

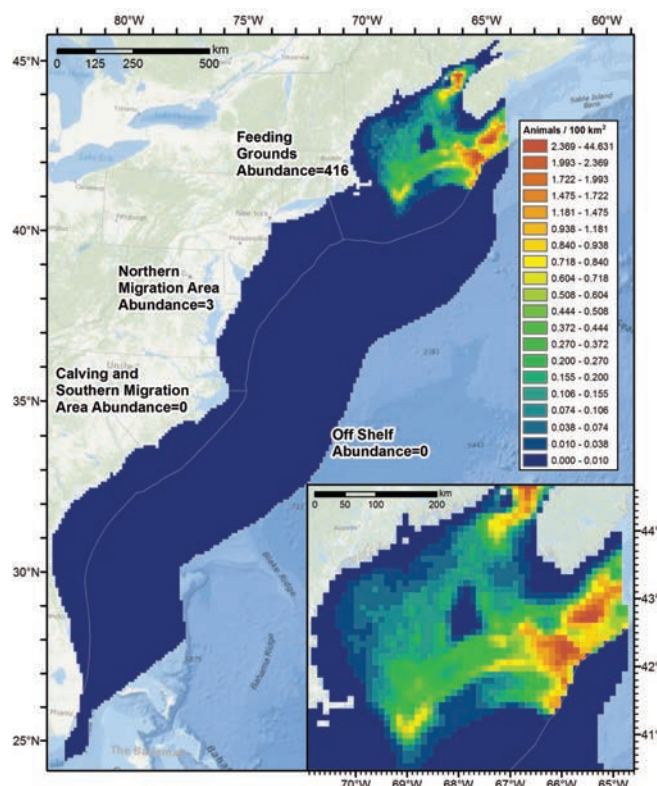
A multi-agency team applied satellite observations to improve assessments of marine mammal habitats and reduce human impacts on whales, dolphins, and other species.

To conduct training exercises at sea, the U.S. Navy files environmental impact statements (EISs) to obtain permits from the NOAA National Marine Fisheries Service. In 2012, the Navy began using the team's models for estimating whale and dolphin density in EIS development. The use supports assessments of potential impacts of sonar-related training and testing, ensuring that its activities comply with environmental and conservation legislation. Improvements to density models and predictions in SDSS support the Navy's submissions of quality EISs, helping reduce revisions and streamlining EIS reviews and permit issuance. The Navy has already benefited from improved data on the density and ranges of Dall's porpoises off the U.S. West Coast.



During this project, the team participated in a working group to map cetacean density and distribution in U.S. waters, particularly to gauge the cumulative effects of sound on cetaceans. The group established a hierarchy of data, identified the best available data, and arranged to make the data available to users via a NOAA website

interface. Working group members unanimously agreed that SDSS and enhancements developed through the NASA project represented the best available estimates of cetacean density.

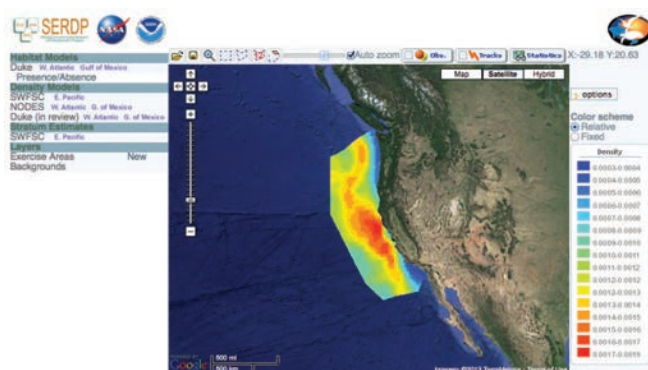


Example of a cetacean density model output for the North Atlantic right whale summer season. This seasonal forecast model uses dynamic oceanographic features (SST fronts, eddies, eddy kinetic energy, etc.) derived from Earth observations.

A May 2012 symposium, Mapping Cetaceans and Sound, featured the models and data hierarchy. It involved more than 200 managers, scientists, and decision makers from the oil and gas industry, Navy, NOAA, and BOEM, among others. This event helped to unify management community and federal agency responses to the assessment and management of ocean noise and potential interactions with protected species. Attendees noted that the accumulation of existing data and density models of cetacean species and ocean noise models in a single repository provides an authoritative baseline source for future protected species management.

“The NASA-funded project . . . has significantly advanced our understanding of how marine mammals are utilizing the ocean,” said James Michael Price, marine mammals studies coordinator at BOEM. “With more reliable knowledge of where and when these animals are feeding, breeding, or migrating through, BOEM can better assess possible adverse impacts to them and, hopefully, take administrative action to avoid the impacts or at least mitigate them.”

In 2012, NOAA and BOEM integrated data from the project into the Multipurpose Marine Cadastre, an



The Spatial Decision Support System provides information on cetacean densities and habitats. The density estimate depicted is for sperm whales, an endangered species, in the summer season in the California Current system. Warmer colors indicate higher density.

integrated marine information system that provides legal, physical, ecological, and cultural information. Originally created to support offshore renewable energy siting, this tool provides a common geospatial framework for broader coastal and marine spatial planning, aiding people working on regional and state coastal and marine spatial planning efforts. The integration of the project's data in this mapping tool helps improve ocean navigation and lower risks of ship-marine mammal collisions and the associated impacts on the animals.

NOAA also reviewed the density models and incorporated them into a new NOAA tool to gauge the cumulative effects of sound on cetaceans. The U.S. Coast Guard indicated it plans to assess in 2013 applications of the team's methods to help forecast fishing areas for more efficient enforcement.

The Strategic Environmental Research and Development Program, a DoD-EPA-DOE partnership, sponsored the development of the Spatial Decision Support System.

Patrick (Pat) Halpin led this project: phalpin@duke.edu. To learn more about the system, visit http://seamap.env.duke.edu/seamap2.5/serdp/serdp_map.php.

Enhancing Conservation

Marine Geospatial Ecology Tools (MGET) is an open-source toolbox for marine research, conservation, and spatial planning. The system supports activities from downloading and conversion of data into popular formats to modeling species habitats and calculating species diversity grids.

Duke University's Marine Geospatial Ecology Lab, which managed the SDSS project, expanded the development of MGET and access to Earth observations for the development of models and analysis in marine ecosystems.

The MGET toolbox includes more than 300 tools and key algorithms. There are tools to identify fronts and eddies in satellite images, evaluate models of species habitats, model biological connectivity, simulate hydrodynamic larval dispersal, build grids to summarize fishing effort, and create habitat maps.

For example, MGET supports forecasting activities for scientific larvae surveys in the Gulf of Mexico and

Caribbean. Forecasts use data on ocean conditions derived from satellite data in models to help guide research ships to the most favorable locations to conduct their sampling. MGET tools automate steps to process satellite imagery and oceanographic model outputs to provide the forecasting products.

In 2012, the Wildlife Society's Spatial Ecology and Telemetry Working Group recognized the MGET development team, led by Jason Roberts, with an award for a “spatial function, tool or service that has significantly enhanced the field of wildlife conservation and management.”

In addition, Esri honored the Marine Geospatial Ecology Lab with a Special Achievement in GIS Award, in recognition of contributions to marine science and its “outstanding work with GIS technology.”

To learn more about MGET, visit <http://mgel.env.duke.edu/mget>.

Enhancing Detection of Risks, Seepage, and Damage in Levees



Levee monitoring and related water management are substantial responsibilities for the California Department of Water Resources (CDWR). An Applied Sciences project collaborated with CDWR to apply NASA's UAVSAR sensor in levee monitoring, complementing other inspection methods and helping assess levees across broad areas. During validation efforts in 2012, the project identified cracks and assessed problems in three levee systems.

The Sacramento–San Joaquin River Delta is the core of the water distribution system of California, through which two-thirds of Californians and millions of acres of farmland obtain water. The delta includes 1,800 kilometers of levees and around 70 islands. Maintaining the levees is essential to prevent flooding. In the western part of the delta, levees are particularly important to avert saltwater intrusion, which would contaminate water for drinking and irrigation and potentially harm the wildlife habitat.

With funding from Applied Sciences, a project team led by JPL's Cathleen Jones collaborated with CDWR to assess the feasibility of evaluating levees with radar remote sensing. In 2012, the project showed that the radar data offered high resolution monitoring of ground surface changes over large areas at one time to detect movement on and near levees and to locate seepage through levees. With such information, CDWR can target in-depth inspections and repairs.

"If this technology saves even one island from levee failure, then it's been very worth the time and energy,"

said Joel Dudas, a senior water resources engineer at CDWR.



The team applied NASA's UAVSAR instrument, which is a polarimetric synthetic aperture radar. It sends pulses of L-band microwave energy to take observations of land cover and topography, detecting land surface deformations. Every month from 2009 through 2012, NASA's Gulfstream III aircraft carried UAVSAR to image the entire Sacramento–San Joaquin Delta and Suisun Marsh. The project conducted the airborne surveys along nine overlapping flight lines to observe each levee from at least three different directions.

The project team used interferometric processing



Levee repair in the Sacramento–San Joaquin River Delta.

techniques to evaluate the levee status by detecting changes in a section of a levee relative to area around it. The team measured subsidence rates throughout the islands with sufficient resolution to detect anomalous subsidence on and near the levees. The team also developed an advanced dynamic subsidence model to support assessments of key factors in subsidence and levee changes. The model accounts for factors such as land use, soil type, and deep-zone natural gas withdrawal. The model allows CDWR and the project team to analyze subsidence rates and determine which factors were the probable causes of subsidence in a given location.

Pinpointing Risks

In 2012, the UAVSAR application identified several levee areas where changes and subsidence indicated potential problems. For instance, data indicated areas on Sherman Island with long-term subsidence along the levee's land-side slope and its toe berm. An area of land behind the levee was subsiding a few inches a year. This high rate of subsidence was very clear in the radar data but not something that CDWR would have noticed in visual inspections from vehicles or on foot. As a result, CDWR added soils to the area in 2012 and planned routine monitoring in future years.

UAVSAR data indicated anomalous changes to an area on the levee on Jersey Island. CDWR passed this information to the engineering firm responsible for levee maintenance, and the firm found a crack in the levee during ground inspection of the area and subsequently repaired the levee. In addition, the team monitored the site of a cracked levee on Bradford Island, which a ship struck and damaged in 2009. CDWR had repaired the levee, and the project assessed the use of UAVSAR to track the repair and ensure settling occurred as expected. The application proved successful at identifying ground movement on and near the levees to enable targeted inspections, demonstrating the value of combining remote sensing with traditional levee health monitoring techniques.

During the project, the team developed a method to identify seeps using short temporal baseline coherent change detection during tidal extremes. High tides are more likely to result in water flowing under levees in the delta rather than overtopping them. During seepage, water can pick up soil and cause erosion that threatens to undermine levees. In 2012, the team validated the technique successfully with CDWR managers. The ability to identify seepage areas will be of particular value during floods.

“What we hope to get out of all this is a tool that will assist in rapid assessment of levee distress that we would otherwise not be able to see,” said Dudas.

California worked with an Applied Sciences project team to apply NASA radar technologies in levee monitoring to assess levee integrity, identify risks, and mitigate threats to water systems.

The team also met in late 2012 with the Sacramento Office of Emergency Services, California Emergency Management Agency, and CDWR Flood Operations Center. The state of California pledged \$225,000 to fund additional UAVSAR flights every six weeks in 2013–2014. The flights will continue activities that allow monitoring of levee areas that are changing more slowly. In 2013, the project team will transfer its methods and will work with CDWR on ways to use other available radar instruments for levee monitoring.

Complementing Inspection Methods

Radar remote sensing complements the knowledge of experienced managers and other levee inspection methods by CDWR and other organizations. In addition to collecting data over large areas and identifying areas for in-depth inspections, radar can collect data at night, in poor weather conditions, and for emergency response. During storms, new seepage can occur. Radar remote sensing can aid in detecting seepage and provide information that allows managers to send repair crews out to priority levees quickly. In fact, part of the Applied Sciences project has been to support preparations for a future emergency during which UAVSAR data could be used to detect and direct response to the most endangered levees.



“UAVSAR is a ‘game changer,’” said Gerald Bawden, a geophysicist and assistant hazards coordinator with the U.S. Geological Survey. “Its radar can penetrate grasses on a levee flank to detect water seeping through the levee, and it can allow scientists and levee managers to identify and understand how land subsidence, active tectonic faults, and landslides impact levee safety.”

Pursuing Other Applications

The project team has presented its work to the American Society of Civil Engineers, U.S. Department of Homeland Security (DHS), U.S. Army Corps of Engineers (USACE), and others. Based on meetings with these groups, the team collaborated with a group of civil engineers at Rensselaer Polytechnic Institute, led by Victoria Bennett, to combine UAVSAR monitoring of levees in the New Orleans area with in-ground instruments that measure levee movement. As a result, DHS plans to incorporate the project’s monitoring techniques into an upcoming DHS playbook on the use of remote sensing for levee management. DHS also invited the project team to speak with its Dam Sector Working Group in 2013 about the remote sensing application and CDWR-project outcomes.

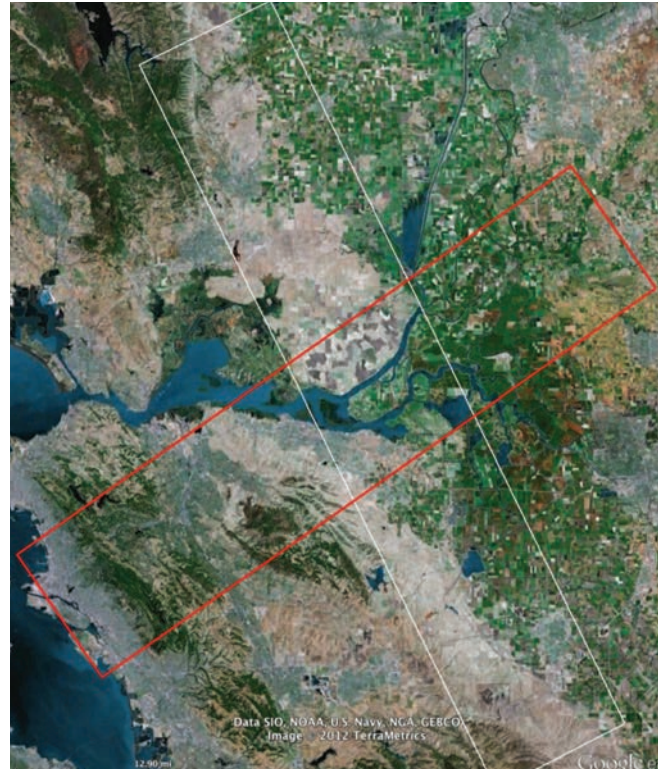
Due to the project, California is funding additional flights of a NASA radar sensor to assess levee integrity and support targeted inspections and areas for levee repairs.

In early 2013, the project team will engage managers in California as well as USACE, DHS, and the U.S. Coast Guard to gather feedback, validate additional data, and put data products in a format that emergency responders can use easily and rapidly in the event of an emergency.

Overall, the project has shown that radar remote sensing offers insights into threats to levees and ones at high risk due to subsidence of the nearby land. The UAVSAR data, models, and application techniques support decisions on levee inspections, repairs, and upgrades.

CDWR now has an objective and verifiable source of information with the spatial extent needed to cover all the levees in the area, and with sufficient ground resolution and temporal frequency to detect changes indicative of potential levee failure.

Cathleen Jones leads this project:
cathleen.e.jones@jpl.nasa.gov. To learn more about CDWR, visit www.water.ca.gov.



Maintaining the levees in the western part of the Sacramento–San Joaquin River Delta supports protection of the freshwater supply. As shown in this image, an area of project focus was Sherman Island, the westernmost island in the delta. The boxes outline the image swaths of two UAVSAR flight lines centered on that island.

Improving Climate Zone Information for the Building Industry



The ASHRAE organization publishes standards that guide the development of state and local building codes and influence building standards worldwide. ASHRAE worked with a NASA team to apply Earth observations in an enhanced method of identifying climate zones. Based on project results, ASHRAE will incorporate in 2013 the project's global climate maps into its Standard 169, which covers climate zones and design conditions.

ASHRAE (formerly the American Society of Heating, Refrigerating and Air-Conditioning Engineers) takes into account the climate in its recommended design criteria. With the U.S. Department of Energy, ASHRAE develops climate zone maps used to establish building codes that promote energy efficiency, safety, and suitability to the local climate. This climate zone information helps architects and engineers select appropriate materials and technologies when designing structures.

The Applied Sciences project used outputs from NASA's MERRA (Modern-Era Retrospective analysis for Research and Applications), a long-term synthesis of meteorological variables used for investigating climate variability. Applying the GEOS-5 data assimilation system, MERRA incorporates a wide variety of surface- and satellite-based measurements, including *Aqua*, *QuikSCAT*, and *Terra*.

The project assessed applications of MERRA data to generate climate zones for the more than 5,500 worldwide locations listed in ASHRAE's most recent *Handbook-Fundamentals*. Distribution of the *Handbook*

exceeds 50,000 members worldwide, including architects, design and manufacturing engineers, building code officials, and facility managers, among others. ASHRAE indicated that it envisions using the project's findings in the 2017 edition of the *Handbook*.



Enabling Global Coverage

Generation of the climate zones stem from meteorological data drawn from time series of at least 10 years of hourly observations, but more often 25 years. The dominant climate is an average of local and regional observations over many years. Some locations or regions may lack observations, or the time series of observations may have gaps at a particular location. For instance, while the 2009 ASHRAE *Handbook* includes climatic information from

A climate zone in the Great Plains, covering an area from northern Texas to southern Kansas, is moving northward at a rate of about 50 miles a decade.

more than 5,500 sites worldwide, it contained none for Ethiopia and two for Kenya.

Applications of NASA Earth observations enabled ASHRAE, an international building standards organization, to develop climate zone maps where none had existed.

The MERRA data sets provide global coverage, and they are temporally and spatially continuous. Thus, outputs from MERRA enabled ASHRAE to achieve better spatial coverage of estimated yearly climate zones. The global coverage of MERRA was especially significant to regions without reliable or sufficient time series of meteorological data to define climate zones. In particular, the project used MERRA surface temperature, relative humidity, and precipitation in determining climate zones.

“The use of NASA’s work has provided an invaluable complement to ground-based data by expanding the geographical coverage to regions with few or no ground stations,” said Didier Thevenard, chair, ASHRAE Technical Committee 4.2 (Climatic Information). “In particular, establishing climate zones for use with building energy codes would have been nearly impossible outside of North America and Europe without the data made available by NASA.”

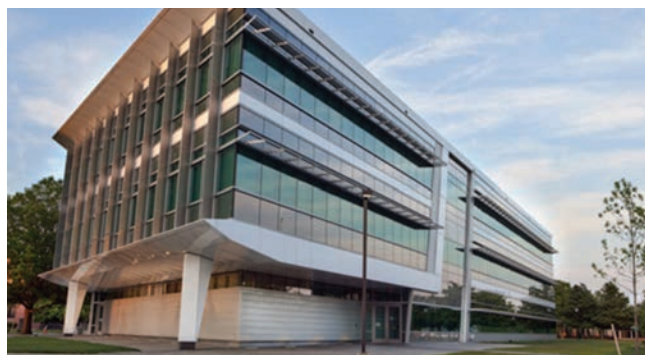
Examining Local Implications

In reviewing the past three decades, the project team observed apparent regional changes in climate. It identified that warmer climate zones in the continental United States are expanding and moving north. For example, one of the warmer climate zones in the United States, covering a region from northern Texas to southern Kansas, is moving northward at a rate of 80 kilometers (50 miles) a decade. The team also identified that cooler climate zones are shrinking in size and that some zones are migrating west, implying a warming of the mountainous western states.

Climate zone information can support efforts to increase energy efficiency. In the United States, buildings consume some \$200 billion in energy annually, and commercial and industrial buildings account for more than 40 percent of the annual energy use of the economy.

Thus, consideration of the appropriate current and future climate zones for buildings represents significant opportunities for energy efficiency and economic gains.

Drury Crawley, chair, ASHRAE Standard 169, noted: “ASHRAE Standard 169 is the basis for determining climate zones and related design conditions for the U.S. energy and green standards . . . used as the basis for U.S. and international model energy codes. NASA provided data which allowed the Standard 169 committee to construct worldwide climate zone maps where none had existed.”



In 2013, the team will publish a manuscript in *ASHRAE Transactions* on the use of MERRA data for calculation of climatic design conditions. The team will develop Web tools to make its outcomes more generally available. The project’s work using the MERRA data is expected to shape the next *ASHRAE Handbook*, scheduled for 2017.

Paul Stackhouse leads this project: paul.w.stackhouse@nasa.gov. To learn more about MERRA, visit <http://gmao.gsfc.nasa.gov/merra>. To learn more about ASHRAE, visit <http://ashrae.org>.

Supporting Early Warnings of Infectious Diseases with New Global Risk Maps



The World Health Organization and nations' health officials now have access to global risk maps of infectious diseases associated with viral hemorrhagic fevers on a biweekly basis. Applying data on environmental conditions derived from *TRMM* and other satellites, the risk maps support early warnings of outbreaks and aid health officials' preparedness.

Viral hemorrhagic fevers—such as Rift Valley fever, Marburg hemorrhagic fever, and Ebola—involve bleeding disorders and elevated body temperatures. The diseases affect humans and are especially deadly for livestock. Agents of transmission include types of insects and bats, and inter-annual climate variability and ecological dynamics influence spatial and temporal factors in disease outbreaks. For instance, heavy rainfall can create breeding sites for mass hatchings of mosquitoes that carry the Rift Valley fever virus.

Earth-observing satellites collect data on surface temperature, precipitation, vegetation, and other environmental parameters associated with the diseases' hosts and vectors. An Applied Sciences team applied and tested combinations of these data products that correlated with historical records of outbreaks. The risk maps the team developed show the probability of environmental patterns related to outbreaks at a given time and place.

Available every two weeks beginning in 2012, the risk maps offer a warning of up to nine weeks prior to an outbreak. Such lead times facilitate timely disease control and prevention, such as collection of surveillance data

and preparations to mitigate the effects of disease. For example, in days preceding outbreaks, public health officials in affected countries can pursue WHO-directed actions such as public education campaigns to mitigate the risks of infection. WHO can coordinate with national institutions to have early warning information, and it can issue international travel guidance.

Satellite-based risk maps of viral hemorrhagic fevers help health officials anticipate outbreaks and take timely actions for disease control and prevention.

“WHO supports development of the [viral hemorrhagic fever] forecasting efforts that improve capacities of existing models to increase the period between a forecasting alert and an outbreak onset,” said Pierre Formenty, lead of the WHO team for emerging and epidemic zoonotic diseases. “The NASA risk maps are an important element towards this end.”

Mapping Risks

WHO, DoD, and the USDA Agricultural Research Service actively participated as technical partners and

“WHO supports development of the [viral hemorrhagic fever] forecasting efforts that improve capacities of existing models to increase the period between a forecasting alert and an outbreak onset. The NASA risk maps are an important element towards this end.”

Pierre Formenty, World Health Organization

end-user representatives in the project, which NASA's Jorge Pinzon led. The team analyzed multiple factors to identify patterns that correlated with outbreaks. The team used *TRMM* precipitation data, land surface temperature from *Terra* and *Aqua*, SRTM topography, and vegetation indices from *Terra*, *Aqua*, and NOAA's AVHRR satellite sensor. Web mapping services supported the display of data and maps through Google Maps, Google Earth, Virtual Earth, and other platforms. Overall, the project proved the feasibility of applying satellite observations to create risk maps, leading to routine production of the maps.

The early warnings enabled by the risk maps also aid livestock management. Officials of veterinary services can allocate resources to FAO guidance such as immunization of livestock and spreading of larvicide at breeding grounds prior to outbreaks.

“The [project's] risk map is a good alert forecasting tool of potential outbreaks [of Rift Valley fever],” said Ken Linthicum, director of the USDA Center for Medical, Agricultural, and Veterinary Entomology.



Broadening Applications

The project team expanded its epidemiological model to other regions and diseases with maps in 2012. The team assessed hantavirus with field data from Ukraine as well as Crimean–Congo hemorrhagic fever with field data from Turkey. In both cases, the project modeled the capacity dynamics of the vectors (rodents and ticks, respectively) as a function of temperature, precipitation, and vegetation. The project reported results of these and other case studies at the 2012 Health & Air Quality applications team meeting.

In 2012, the team also partnered with DoD health officials for advanced awareness of developing infectious disease threats, involving DoD's Global Emerging Infections

Surveillance and Response System. DoD officials indicated that they, EU partner militaries, and the Afghan military will apply the risk maps in 2013, informing decisions from use of tick repellent to the mobilization of medical personnel.

Captain Clara Witt, U.S. Public Health Service Commissioned Corps, and senior scientist, DoD Center for Disaster and Humanitarian Assistance Medicine, said of the risk reporting of the project's maps: “It's the ‘next generation’ of thinking about how remote sensing technology can be used to identify and detect the pre-factors for conditions that lead to disease emergence.”



Increasing Capabilities

The maps represent new capabilities for early warnings of outbreaks, especially in areas like sub-Saharan Africa, allowing action prior to the first symptoms. WHO, FAO, and various countries' ministries of health and agriculture have begun using the risk maps and related predictions to prepare for and mitigate the effects of outbreaks.

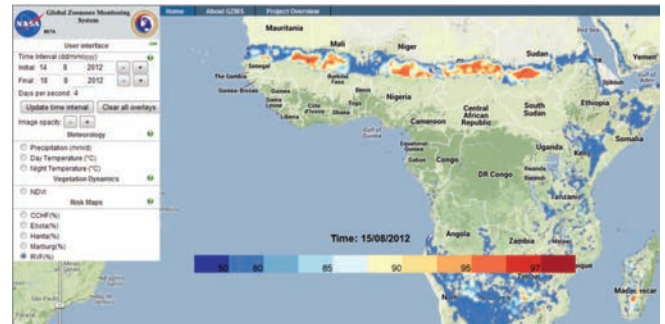
Increasing awareness, acceptance, and use of the risk maps are key challenges. In July 2012, maps indicated risks of Rift Valley fever in portions of Africa. They showed higher-risk conditions moving west from Mali to Mauritania over the summer. The first human cases appeared in mid-September, and the Mauritanian Ministry of Health declared an outbreak in early October.

The project experienced a setback in 2012 on the Web-based hosting for the risk maps. Late in the project, a key partner organization notified NASA that due to resource

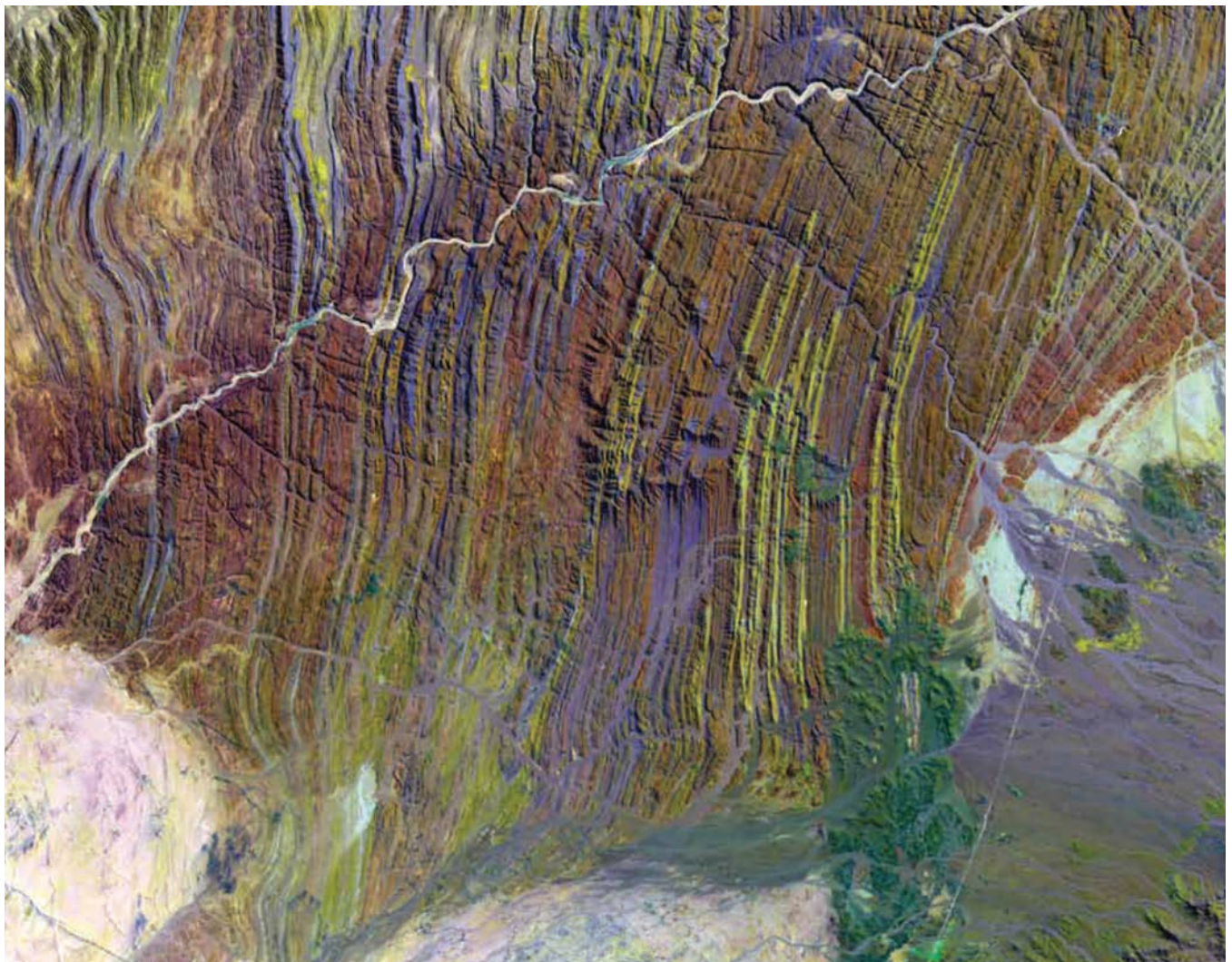
reductions, it would not be able to host the maps as originally planned. In 2013, Applied Sciences will seek to secure a long-term host for sustained distribution of the maps. Until then, NASA has made the risk maps available at <http://rs4gzm.org/gzm> so they remain accessible to health and veterinary officials.

In 2013, Applied Sciences plans to investigate the feasibility of risk map distribution through its SERVIR venture. SERVIR will also raise awareness of the risk maps, supporting surveillance and control activities and efforts to reduce effects on humans and livestock. Among other stakeholders, the team will broaden awareness of its findings and risk maps to more potential end users through journals of zoonotic diseases such as publications of the Centers for Disease Control and Prevention.

Jorge Pinzon leads this project: jorge.e.pinzon@nasa.gov.



An example of a risk map for Rift Valley fever in Africa from mid-August 2012. Warmer colors indicate higher probability of risk, based on environmental factors related to disease emergence.



Ugab River, Namibia.

Earth as Art

Creating and Delivering Tools to Support Hurricane Disaster Response



In October 2012, Hurricane Sandy devastated areas of the mid-Atlantic and northeastern United States, causing flooding, scores of human fatalities, nearly \$50 billion in damage, and power outages for millions. Along with many state and federal agencies, NASA, led by the Earth Science Division, supported the rapid response to the disaster.

In one case, NASA's SPoRT Center (see callout on page 23) created an innovative tool that assisted emergency responders in the immediate aftermath with satellite imagery that highlighted areas without power, allowing decision making to better allocate relief resources. Months before Sandy, Applied Sciences funded SPoRT to examine uses of the new NASA/NOAA *Suomi NPP* satellite for disaster applications.

Applying New Capabilities

Launched in October 2011, *Suomi NPP* carries five instruments. Its VIIRS instrument features a new, low-light capability to image the Earth and atmosphere at all levels of illumination. Known as the day-night band, this VIIRS low-light channel can detect nighttime light from wildfires, urban and rural communities, and other human activity. It can also detect moonlight reflected from clouds and surface features.

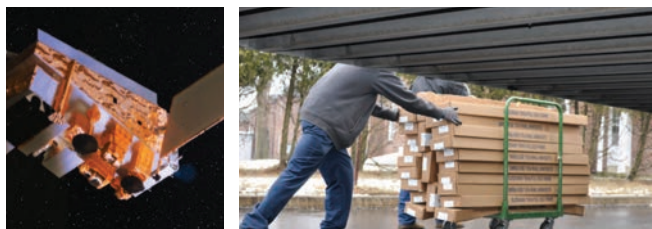
Using VIIRS data received in near real time, the SPoRT team rapidly developed a prototype "blackout composite" from the day-night band. The team combined an image from pre-storm lights (August 31) and an image with lights remaining visible after the storm (November 1) to

identify differences. In the resulting false-color composite, cloud-free areas where light was reduced (suspected outage) appeared in shades of yellow. Further differences between the two dates, such as cloud cover, appeared in other colors. The majority of these outages occurred in coastal portions of New Jersey, the New York City area, and Long Island.



Assisting Action

Many state and federal agencies responded rapidly to the disaster. The USGS Hazards Data Distribution System and the FEMA GIS portal provided means to coordinate information sharing and facilitate greater use among



the responders. SPoRT supplied to these portals the blackout composites and annotated satellite imagery identifying large-scale outages. Other organizations also posted Web-based satellite products documenting damage caused by Hurricane Sandy.

FEMA, the U.S. Army Corps of Engineers, and U.S. Army used the SPoRT products from the portals to monitor areas without power as part of their activities. The imagery offered a rapid, comprehensive perspective to identify possible outages and effectively distribute relief resources. The wide-ranging view allowed emergency managers to organize and allocate personnel, equipment, and supplies and initiate recovery efforts quickly in areas in most need of assistance.

Using new capabilities on *Suomi NPP*, an Applied Sciences project rapidly developed innovative power-outage assessments to support Hurricane Sandy response.

For example, the U.S. Army Northern Command used the SPoRT data on areas of power outage for selecting staging locations for generators. As the Army worked with SPoRT and became more familiar with VIIRS data, SPoRT provided the raw reflectance/radiance data, which allowed Army analyst Kathleen Mumford to develop her own “emitted light” difference product.

Brenda Jones, USGS disaster response coordinator, said to SPoRT: “Thanks so much for sharing. . . . [This] kind of product should be routinely produced for major disasters as an easy reference for power outages and as a recovery indicator.”

In addition, the project team used data from the *Terra* satellite’s ASTER sensor, a joint NASA/JAXA instrument, to assist in disaster assessments. Using ASTER observations, the SPoRT team produced false color composites, which differentiate vegetated surfaces from non-vegetated areas, to identify damaged roads and homes, particularly in New Jersey. Responders used these data products from the USGS data portal as well.

Lt. Col. David Foster, U.S. Army North, said to the NASA team in early November: “We are pushing an additional analysis team into New Jersey to support our Joint Coordination Element (Joint Task Force—Civil Support). They look forward to getting [additional] imagery Your data is one of the invaluable data sets they have and will be leveraging.”

Continuing Assistance

Just five weeks later, Typhoon Bopha struck the Philippines. SPoRT applied the VIIRS-based power outage assessment technique from the Hurricane Sandy assistance. The team supplied data products and annotated images, providing key information in NASA’s overall contributions to this disaster response.

In 2013, the SPoRT team plans to develop automated tools for a wider range of disasters. It will develop a clear sky VIIRS composite of city lights to ensure pre-event data are available for analysis after other disasters that cause power outages, such as earthquakes, severe winds, and winter snowstorms. The team will publish an article on its VIIRS-based power outage technique and Hurricane Sandy support in January in *Eos*, the AGU weekly.

Gary Jedlovec leads this project: gary.jedlovec@nasa.gov.



Suomi NPP launched in 2011, and NASA transferred operational control of the satellite to NOAA in February 2012. *Suomi NPP* has a suite of five sensors, including the VIIRS sensor and its new day-night band.

Short-term Prediction Research and Transition Center

SPoRT, the Short-term Prediction Research and Transition Center, is a NASA Earth science project to transition unique observations and research capabilities to the operational weather community to improve short-term forecasts on a regional scale. SPoRT focuses on the use of advanced NASA modeling and data assimilation techniques, nowcasting techniques, and unique high-resolution multispectral observational data from Earth-observing satellites to improve short-term weather forecasts.

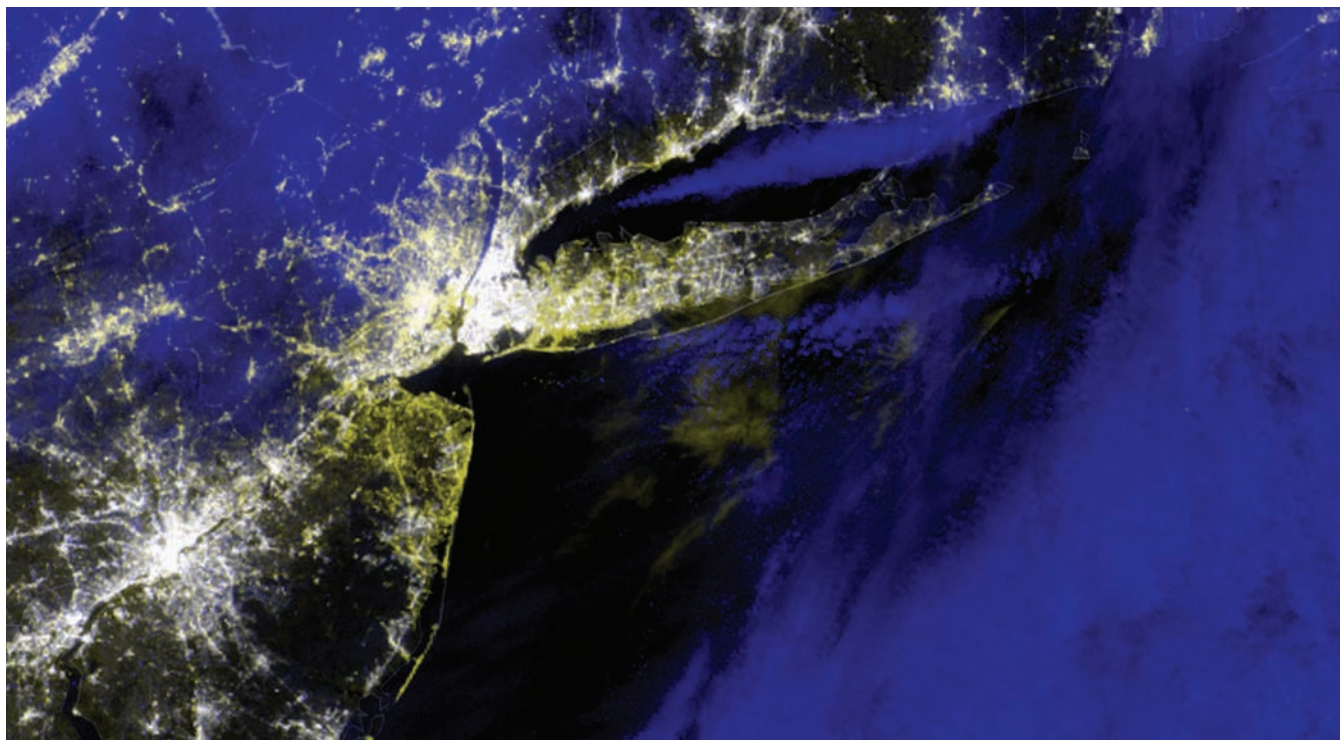
SPoRT serves as a focal point and facilitator for the transfer of NASA Earth science technologies to the operational weather community with an emphasis on short-term forecasting. SPoRT works collaboratively with organizations to develop new products and

infuse these capabilities into the operational weather environment.

The majority of the SPoRT end users are forecasters at various weather forecast offices in the southern United States. The inclusion of private sector users in SPoRT shows the relevance of NASA data and research capabilities to a broader segment of the weather community.

SPoRT operates from NASA's Marshall Space Flight Center in Huntsville, Alabama. SPoRT receives primary funding from NASA ESD's Weather Data Analysis program.

To learn more about SPoRT, visit <http://weather.msfc.nasa.gov/sport>.



A "blackout" composite image of the New York City area for November 1, 2012, derived from VIIRS day-night band imagery before and after Hurricane Sandy. White areas indicate lights, and yellow areas indicate power outages—urban areas with power (lights) before Hurricane Sandy but not after. Northeastern New Jersey and Long Island show the greatest outages. Blue regions are the result of cloud cover.

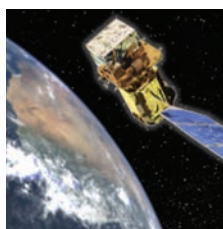
Improving Agricultural Drought Assessment and Informing State Policy



In June 2012, a “flash drought” occurred in Alabama. The 2012 agricultural season in most of the state started with relatively sufficient precipitation and soil moisture. Within a two-week period in June, data showed high levels of crop stress in the northern part of the state.

An Applied Sciences project was already in place and examining new applications of Earth observations addressing agricultural drought in the southeastern United States. The project enhanced resources for decision making about droughts, including development of a real-time crop model using NASA Land Information System (LIS) data and satellite-derived insolation. The model helps assess the impact of drought on agriculture.

During 2012, the project team delivered data products in real time to climatologists, water resources managers, the National Drought Mitigation Center (NDMC), and USDA National Agricultural Statistics Service. Throughout the summer, the state climatologist and the Alabama Office of Water Resources used the crop model in weekly drought status meetings, including teleconferences with NDMC.



Stemming from the project's results on the effects of drought on agriculture, Alabama enacted an irrigation tax credit in 2012.

Analyzing Impacts

After the growing season, the project team analyzed the impact of the flash drought on corn yields from the crop model. The analysis demonstrated that in many areas of northern Alabama, yields were below 50 bushels per acre. (Average for the state was about 110 bushels per acre; a good year would be 130 to 150 bushels per acre.) The analysis identified a short period in June without rain and with high temperatures in northern Alabama.

The project also highlighted the role of severe, short-term droughts in reducing even average agricultural yields. In computing weekly irrigation demand in the Southeast, the team's analysis suggested that only modest irrigation would have increased yields from 50 to 75 bushels per acre (rain-fed) to nearly 200 bushels per acre (irrigated).

NDMC supported the project team's work to improve drought delineation and categorization products for the southeastern United States. In a letter to the project leader Dick McNider, NDMC Director Michael Hayes

“We believe the real-time crop modeling based approach to capture agricultural drought may be applicable to other regions and may have been especially useful during this year’s Midwest drought, which had profound impacts on agriculture.”

Michael Hayes, National Drought Mitigation Center

said: “In our work with you, we have become aware of the special agricultural drought impacts that can occur rapidly due to poor water holding capacities of soils in the Southeast. . . . We want to work with you to develop products under the auspices of the Drought Monitor that can convey this type of drought impact for drought assistance programs.”

Informing State Policy

Benefits of the project preceded its support during the 2012 drought. Earlier in the year, Alabama enacted an irrigation tax credit. Data and analysis from the project in 2011 was part of the information that factored into development of the 2012 bill passed by the Alabama legislature and signed by Governor Robert Bentley. A state senator sponsoring the legislation recognized McNider as being responsible for the legislative initiative.

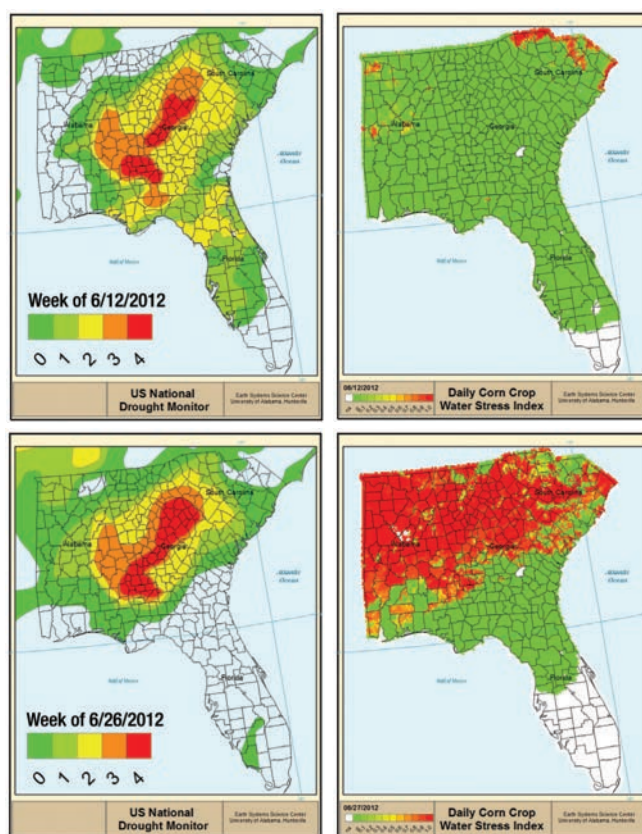


Information from the project factored into an irrigation tax credit bill passed by the Alabama legislature and signed by Alabama Governor Robert Bentley (center) in May 2012. Richard McNider, project principal investigator, is the person directly to the left of Governor Bentley. Legislators sponsoring the bill and other state leaders are with the governor and McNider.

The tax credit, with a limit of \$10,000 per year per farm, is an incentive for farmers to invest in irrigation systems. Policy and water resources experts expect that expanded irrigation will increase revenue for farmers through higher crop yields while reducing costs for poultry and livestock producers through cheaper feed grains.

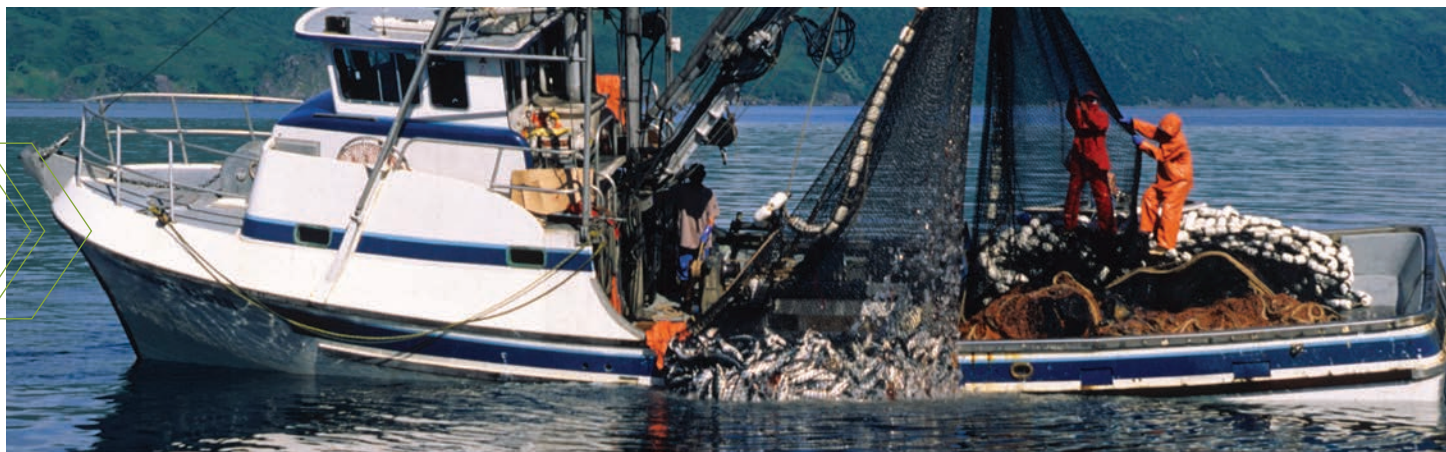
Under a solicitation focused on the Gulf of Mexico region, Applied Sciences funded the project through its Gulf of Mexico Initiative.

Richard (Dick) McNider leads this project: mcnider@nsstc.uah.edu. In late 2012, the American Meteorological Society selected McNider to receive its 2013 Award for Outstanding Contribution to the Advance of Applied Meteorology.



Images from the U.S. Drought Monitor (left) and NASA GridSSAT gridded crop model (right) for June 2012. The top images show conditions for the week of June 12, 2012; the bottom images show conditions for the week of June 26, 2012. The GridSSAT model showed that stress (warmer colors) on corn in northern Alabama developed rapidly during the flash drought; the longer-term U.S. Drought Monitor showed only modest drought. The GridSSAT model uses NASA LIS data and satellite-derived insolation.

Advancing Management of Chinook Salmon Fisheries



Wild Chinook salmon from central California, an important commercial and recreational fishing species, face the risk of extinction in some areas. Accurately estimating the size of populations for future years, which can inform management actions, has proved difficult.

A NASA-sponsored project worked with the Pacific Fishery Management Council (see callout on page 28) and NOAA to apply Earth observations from *Jason-2* and *Aqua* in a stock assessment model, aiding fishery forecasting. Use of the combined observations has added one to two years to forecasts, aiding adaptive management practices to better support the sustainability of Chinook stock.

A novel approach applying satellite observations of ocean environmental conditions improved Chinook salmon stock assessments, aiding management of the fishery.

Siblings and Partners

Management of the central California Chinook fishery has largely relied on a sibling model: the number of three-year-old fish available in a given year is based on the number of two-year-old fish returning to spawn the prior year. In other words, the model that managers have used to estimate the fishable abundance of central California Chinook salmon is only a year ahead of the fishery. As such, abilities for earlier adaptive management are limited.

Using data from satellites, the Applied Sciences project

developed ways to better predict three-year-old fish based on the abundance of krill for juvenile salmon to eat in their first year of life. The project's model adds an additional one to two years to the prediction periods of three-year-old fish. The extended prediction periods allow fishery managers to adapt management practices earlier and reduce variability in the fishery.

Led by Francisco Chavez of the Monterey Bay Aquarium Research Institute (MBARI), the project team included applied researchers from the NOAA National Marine Fisheries Service (NMFS), Farallon Institute, University of Maine, and Remote Sensing Solutions, Inc. Primary end users were NMFS and PFMC, which manages fisheries off the coasts of Washington, Oregon, and California.



In 2012, PFMC technical experts incorporated the project's findings and methods in developing prior season

“The project directly addresses some of the highest priority Council stock assessment and management needs, and could greatly assist the fishing industry in long-term planning.”

Donald McIsaac, Pacific Fishery Management Council

data reports and estimates of the number of fish for the next season. In addition, NOAA began using the project’s models in an integrated ecosystem assessment tool it developed for the California Current.

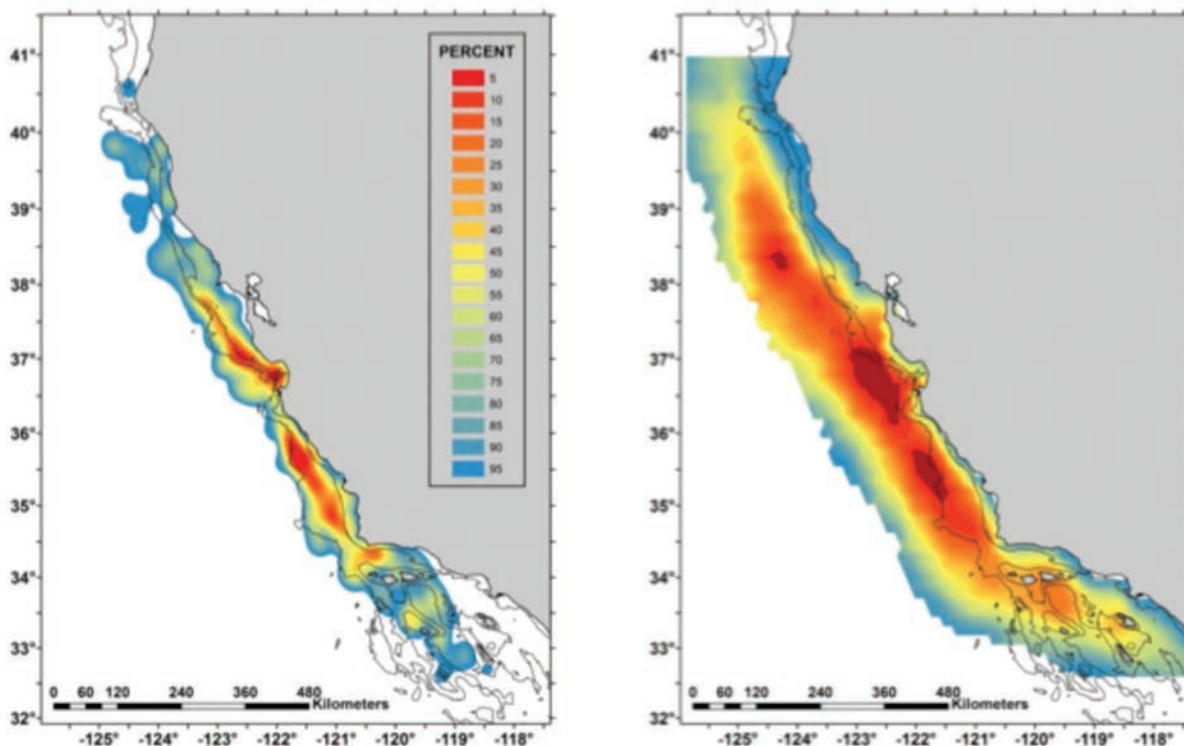
“The California Current Integrated Ecosystem Assessment (CCIEA) is excited about the results of the NASA project,” said Brian Wells, NOAA science lead for the CCIEA. “The CCIEA uses the results to advise management of salmon for central California. Specifically, using the krill-salmon models developed by the project, the CCIEA can gain a predictive understanding of how the productivity of the California Current varies year to year.”

Applying Earth Observations

To create its advanced model, the project team used oceanic environmental data from sources including *Aqua*,

Jason-2, and *GOES*. The team enhanced the sibling model by incorporating sea surface height, while taking into account variables such as temperature, wind speed and direction, and upwelling. The team also used the Regional Ocean Modeling System, developed in part by NASA’s Jet Propulsion Laboratory, to simulate and forecast the ocean environment.

The project team improved estimates of fish returning to spawn by examining the variables that affect salmon returns. It analyzed regional winds, krill data from ship surveys, and ocean circumstances due to climate oscillations. The team noted the wind and ocean layer temperature conditions related to lower coastal sea level. A lower coastal sea level and a large quantity of adult krill provide juvenile salmon with the optimal environment for growth and survival.



Comparison between the relative concentration of krill along central California estimated using acoustics on ship surveys (left) and a similar measure estimated from the project’s model simulations (right). Using percentiles of krill abundance from a cumulative histogram approach, the colors indicate the percentage of the concentrations at 5 percent intervals (highest in the 0 to 5 percent range, lowest in the 90 to 95 percent range). Warmer colors indicate higher concentrations of krill.

The team's findings allow for a two-year lead on the sibling model. In the spring, as adult salmon return to spawn, fishery managers can combine estimates of krill abundance and forecasts of sea level height for the fall—with time to amend, if necessary, harvest rules.

Increasing Accuracy

Using its model, the project improved forecasting accuracy by 20 percent in comparative hindcasts. The fit of the sibling model results to the observed data accounts for 60 percent of the variability in the data. Fishery managers generally consider that a reasonable fit, and the simple approach works well during periods of average or above average abundance. However, in a period of significantly reduced stock, fishery managers need to ensure the survival of enough spawning fish to allow the population to recover.



"The project has and will continue to provide valuable insight into the effects of ocean environmental conditions on Sacramento River fall Chinook, the most important Chinook stock supporting ocean fisheries in California and Oregon," said Donald McIsaac, executive director, PFMC.

Adoption of the project's predictive techniques should support long-term planning in the fishing industry. Due to its enhancements to the sibling model and ecosystem perspective, the project also has implications for other forage species and managed stocks. The project is due to complete in 2013.

Francisco Chavez, MBARI, leads this project:
chfr@mbari.org.

Managing Fisheries

The Magnuson-Stevens Fishery Conservation and Management Act of 1976 established eight regional fishery management councils. The councils manage fisheries with the best available science and incorporate ecosystem management practices when possible. NOAA NMFS implements the management measures recommended by the councils.

One of the eight councils, the Pacific Fishery Management Council, has jurisdiction over approximately 315,000 square miles of exclusive economic zone off Washington, Oregon, and California. It manages fisheries for about 119 species of salmon, groundfish, coastal pelagic species (sardines, anchovies, and mackerel), and highly migratory species (tunas, sharks, and swordfish).

PFMC scientific and technical groups use models and other forecasts and simulations. At the beginning of every year, PFMC uses the technical experts' data and estimates to make recommendations on management measures, such as fishing quotas, gear restrictions, and curtailment of season length.

To learn more about PFMC, visit www.pcouncil.org.

Tracking Global Crop Conditions for Improved Production Assessments



Severe droughts hindered crop production in major portions of the Northern Hemisphere in 2012. The United States, which produces more than a third of the world's corn and soybeans, experienced its worst drought in more than 50 years. Large areas of western and central Eurasia, which account for a quarter of the world's wheat exports, also suffered from extensive drought.

Already under way in 2012, a Program-sponsored project applied satellite-based indices of crop conditions to monitor major crop producing regions, identify anomalies, and inform production forecasts months before harvest. The team includes leaders in international activities to improve global agricultural monitoring, food market transparency, and food security.

Assessing Crops

The project team applied a remote sensing indicator of vegetation vigor known as NDVI (see callout on page 30). The team looked at NDVI anomalies and compared them with the peak NDVI times, pinpointing critical stages in the growing season when crops would be especially sensitive to high temperatures and low precipitation.

Using MODIS data from *Terra* and *Aqua*, the project assessed the 2012 growing season in the Northern Hemisphere, computing a time series of daily vegetation images of primary cropland areas. Comparisons of current crop conditions with average conditions for the same date from 2000–2011 showed NDVI anomalies beginning around May. A series of images from May through September 2012 showed the intensification of droughts and impacts on cultivated areas in the United

States and parts of Eurasia. Notably, the images also pointed to generally favorable conditions in the main growing areas in Canada and China.



The team's analysis indicated widespread crop damage during critical growth stages, especially in the Corn Belt in the United States, and in the wheat growing regions in Russia, Ukraine, and Kazakhstan. Indeed, the production in all these regions was below average. For the United States, corn production in May–June was down about 100 million metric tons.

Comparisons of growing seasons offered insights into the state of current crops relative to prior years with detrimental droughts. For instance, the team compared the NDVI crop anomalies over Eurasia in July 2012 with the NDVI anomalies in July 2010, when large areas

suffered severe droughts. The 2012 NDVI anomalies were akin to those from 2010 for Russia and Kazakhstan. Since grain production fell 30 percent in Russia during the 2010 drought and wheat prices rose, officials and markets could anticipate similar, significant disruptions.

When severe droughts hit in 2012, an Applied Sciences project was already applying satellite observations to monitor global agricultural production.

Developing Capacity

These efforts were part of broader ones to build global agricultural monitoring capabilities. The team shared its imagery and assessments with an international expert panel formed by the Group on Earth Observations (GEO), including representatives from FAO, main producer countries (Canada, China, Kazakhstan, Ukraine, the United States, and Russia), and the Joint Research Center of the European Commission. The panel examined national, regional, and global crop condition indicators, which complemented the project's, and developed a consensus Northern Hemisphere crop outlook.

NASA, through ESD and Applied Sciences, actively supports the GEO Global Agricultural Monitoring initiative, or GEO-GLAM. The project directly supports GEO-GLAM's efforts to develop a timely, consensus assessment of production for the primary producer countries, with as much lead time as possible in advance of official national statistics. Crop monitoring helps identify areas with likely shortfalls or surpluses in food production. Such information and lead times can help markets reduce price volatility.



"I am confident that this project, combined with the international coordination and harmonization occurring through [GEO-GLAM], will deliver to agricultural forecasts the same benefits that have been experienced with improved accuracies of weather forecasts when

space-based observations were incorporated into the global weather models," said Barbara Ryan, director, GEO Secretariat. "In the case of agriculture, improved production forecasts will reduce price volatility, which ultimately will create a more food-secure world—something for which we all should strive."

Plowing Forward

In the fall of 2012, the team began assessing crop conditions in the Southern Hemisphere. The team completed the wheat assessment of the Southern Hemisphere in December, and will complete assessments of corn and soybeans in the spring of 2013.

"Although still in development, this [crop outlook] initiative has already raised much interest internationally among policy makers, space agencies, and agricultural ministries," said Joao Soares, scientific and technical expert for agriculture, GEO Secretariat.

With GEO-GLAM and international partners, the project will develop efforts to disseminate crop condition

NDVI

Earth-observing environmental satellites can measure outside the visible range of light, viewing across multiple wavelengths and seeing more than what is visible to the naked eye. Scientists have identified that some wavelengths are more sensitive and revealing of vegetation than others.

For example, healthy vegetation absorbs most of the visible light that reaches it and reflects much of the near-infrared light. Combining those vegetation-sensitive wavelengths in special ways can provide insights on crop health and stress.

The Normalized Difference Vegetation Index (NDVI) is such a combination. NDVI is an established indicator calculated from differences in the visible and near-infrared light that vegetation reflects. NDVI supports assessments of whether a target being observed contains live green vegetation, and it serves as a measure of the physiological activity of plants.

By assessing the NDVI at particular times in the growing season over many years, managers can assess NDVI anomalies, or departures from average conditions. Peak NDVI varies by crop and region. For instance, peak NDVI for wheat occurs in May in the United States and in July in the Black Sea region.

outlooks and production forecasts through the Agricultural Market Information System (AMIS). AMIS is a G20 initiative to enhance food market transparency and encourage coordination of policy in response to market uncertainty. The project's outcomes support the focus of AMIS on wheat, soybeans, rice, and corn as well as its transparency and policy coordination goals.

The project will also test NDVI applications from the VIIRS sensor on *Suomi NPP* as a continuation and eventual transition from MODIS on *Terra* and *Aqua*. The team is building, with international partners, an online platform to share its findings and identify drought “hot spots.” The platform will encourage users to upload data and provide comments.

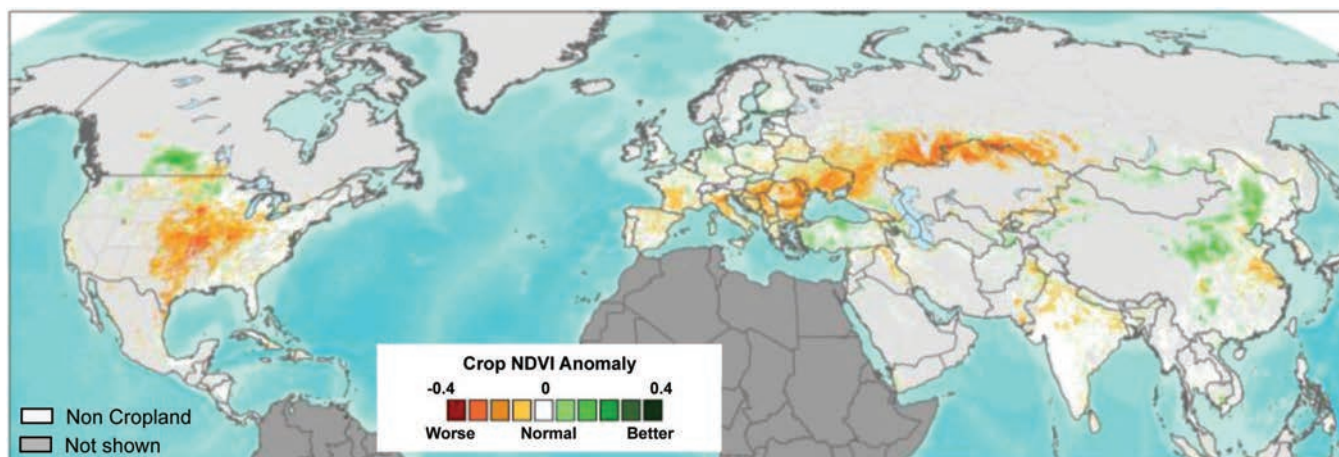
Overall, the project has made great strides in advancing the use of Earth observations for monitoring major crop producing regions critical to global food markets.

Government officials can use the information, for example, to make more informed estimates of food stocks, plan emergency reserves, and implement policies to reduce food price volatility.

Chris Justice and Inbal Becker-Reshef lead this project: justice@hermes.geog.umd.edu and ireshef@hermes.geog.umd.edu.

“The assessments have been able to demonstrate to decision makers the value and utility of remotely sensed derived information for providing timely and actionable information on crop conditions.”

Joao Soares, GEO Secretariat



This figure shows Northern Hemisphere crop NDVI anomalies in mid-August 2012 compared with average conditions for the same date from 2000–2011. Browns indicate worse than normal conditions, and greens indicate better than normal conditions. Major cultivated areas in the United States, Russia, Ukraine, and Kazakhstan show significant anomalies and impacts to production.

Enhancing Environmental Information for Public Health



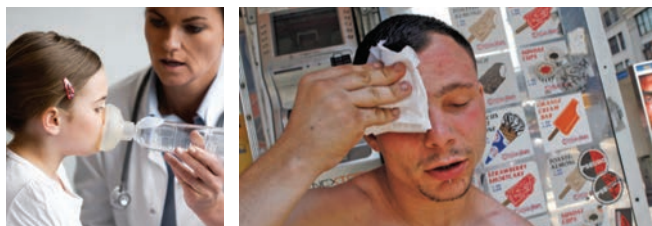
The Centers for Disease Control and Prevention (CDC) promote health and prevent diseases by facilitating access to public health information for state and local health departments, the academic public health community, and the U.S. Public Health System.

Working with CDC, an Applied Sciences project enabled the integration of satellite-based environmental measurements into a key CDC health information system. In 2012, the project team also contributed to a major national health study, linking environmental factors and certain health outcomes such as stroke.

Enhancing WONDER

The CDC Wide-ranging Online Data for Epidemiologic Research (WONDER) system provides databases and query tools for the analysis of public health by health officials, researchers, and medical practitioners. WONDER includes data on environmental factors, such as heat waves and air quality, shown to influence human health or exacerbate health risks.

By the end of 2012, the NASA-sponsored project had enabled the integration into WONDER of several



The CDC WONDER system now includes data on satellite-derived temperature, air quality, and other parameters for health professionals to account for environmental exposure in human health.

environmental parameters derived from Earth-observing satellites. For example, the project team produced daily, gridded air quality estimates of fine particulate matter (PM_{2.5}) for inclusion in WONDER, using data from *Aqua* and the EPA Air Quality System. The team generated heat-related products and solar radiation (insolation) maps for the conterminous United States using the NASA NLDAS-2 meteorological analysis data set. The team also produced daily, gridded land surface temperature maps using data from MODIS on *Aqua* and *Terra*. Users of WONDER can now query MODIS land surface temperature for a specific period, generating maps, charts, or tables according to their specific criteria.

“These data . . . provide a useful addition to CDC WONDER, allowing public health researchers and policy makers to better include environmental exposure data in the context of other health data available in the CDC WONDER system,” said Sigrid A. Economou, public health informatics specialist, CDC.

"These data . . . provide a useful addition to CDC WONDER, allowing public health researchers and policy makers to better include environmental exposure data in the context of other health data available in the CDC WONDER system."

Sigrid A. Economou, Centers for Disease Control and Prevention

WONDER allows practitioners and the public to query an array of health-related data sets. For instance, state and local health officials can use the air quality data to assess local trends or identify apparent linkages with emergency room visits and health care costs. They can obtain information to update protocols for public health alerts during heat wave and smog events.

The inclusion of the environmental remote sensing data in WONDER also enabled its distribution and availability to broader, nontraditional audiences. The *County Health Rankings*, which rank the health of nearly every county in the nation, used the PM2.5 air quality data developed by the team and obtained via CDC WONDER. The CDC Office of Surveillance, Epidemiology, and Laboratory Services is using the PM2.5 data to update the Community Health Status Indicators website. In addition, Google Inc. requested from CDC WONDER the application programming interface for the NLDAS air temperature and health index, in order to include the data in Google's Public Data Explorer.

At the end of 2012, CDC WONDER analyzed its website statistics and reported that the addition of the NASA environmental data sets to the site had increased its usage by nearly 80,000 visits in 2012.



Earth Science Serving Health

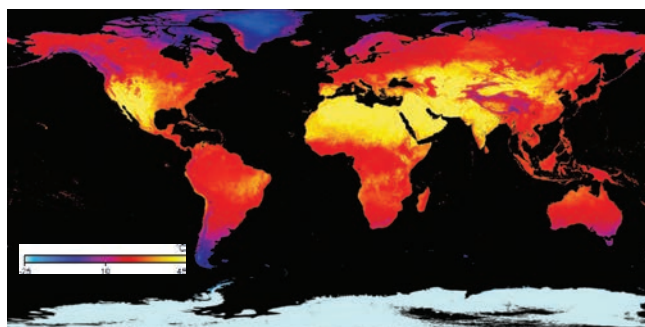
The project team includes professionals from the University of Alabama at Birmingham (UAB), NASA Marshall Space Flight Center, and Universities Space Research Association. In 2012, the team shared its data products with the UAB School of Public Health, which is leading a national health study called REasons for Geographic And Racial Differences in Stroke (REGARDS). Sponsored by NIH, REGARDS is investigating regional and racial disparities in stroke incidence for people aged 45 and older. The project team linked the satellite-based estimates of PM2.5, solar insolation, and land surface

temperature with data from the more than 30,000 participants in the study. The objective was to determine whether exposure to the environmental variables correlated with cognitive decline, stroke, hypertension, and other health conditions.



The team's data products and analyses supported the identification of groups at high risk of cardiovascular disease, and they offered additional insights into illness and prevention. The project team will publish a paper in early 2013 on short- and long-term sunlight radiation and stroke incidence. It will also publish on the relationship between environmental variables and other health conditions, such as high blood pressure, among REGARDS participants.

Leslie McClure leads this project: lmccclure@uab.edu. To learn more about the data products, visit <http://wonder.cdc.gov/EnvironmentalData.html>. To learn more about REGARDS, visit www.regardsstudy.org.



Daytime land surface temperature for June 2012 from Terra/MODIS. Warmer colors indicate warmer temperatures; black means no data.

Furthering Wildlife Habitat Conservation and Management



The U.S. Fish and Wildlife Service (USFWS) manages the 150 million-acre National Wildlife Refuge System and initiatives by states, territories, and tribes for fish and wildlife monitoring and conservation. In general, efforts to sustain species populations through habitat management depend on an understanding of the environmental factors that affect these populations.

Together with USFWS, an Applied Sciences project developed a system of tools supporting applications of Earth observations and ecological forecasting for fish and wildlife management. The project team utilized features of satellite remote sensing to provide environmental information on broad areas and large ecosystems, such as national parks and wildlife refuges, and at finer, species-level spatial and temporal scales. The project team created an adaptable, unifying architecture known as EAGLES—the Ecosystem Assessment, Geospatial analysis, and Landscape Evaluation System. The team validated key aspects of the system in 2012.

Enabling Data Access and Use

EAGLES provides a series of linked software applications in ArcGIS and Web-enabled environments, incorporating Earth observations for ecological forecasts. For example, EAGLES includes data products from MODIS (snow and vegetation), SRTM (elevation), and AVHRR (solar radiation), among other sources. It also includes geospatial covariates (explanatory variables) from remote sensing data, data products, and ecosystem models using MODIS and *Landsat* data. The satellite observations complement data from conventional

monitoring of large ecosystems through field plots and aerial surveys.

The new EAGLES system broadens ways for fish and wildlife managers to apply Earth observations for habitat management and species conservation.

EAGLES allows biologists and managers direct control and access to powerful data processing and modeling capabilities for landscape planning and management of focal species and their habitats. The system reduces the data storage and computation capabilities needed to create customized environmental covariates.

The EAGLES system incorporates legacy data—data in older formats that state and federal agencies have collected over several decades, largely from ground-based surveys. For instance, the team enabled access to legacy data on focal species populations such as bison and pronghorn sheep. In validating the system, the team merged the legacy species data with the covariates to carry out diagnostic analyses and predictive modeling of habitat distribution and birth and death rates. Such

“The Fish and Wildlife Service manages trust resources . . . at the continental scale that are constantly responding to a changing environment. And COASTER allows you to conduct rapid assessments of environmental effects such as climate change almost anywhere in North America.”

Kurt Johnson, U.S. Fish and Wildlife Service

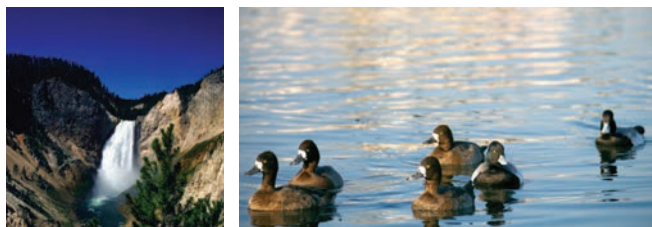
capabilities can help EAGLES users to better understand the impacts of climate and other environmental factors on species populations.

Assessing Alternatives

The team developed tools to forecast species distributions based on habitat and climate projections. Users can devise and analyze “what-if” scenarios (e.g., future climate conditions, land development, and wildfire disturbances) and their associated outcomes. These and other capabilities inform decisions by USFWS and similar entities to, for example, regulate land use, develop climate adaptation strategies, or restore habitats.

“We are using data provided by [the project team] to better determine how waterfowl populations in the North American prairies will respond to system change,” said Kathy Fleming, landscape ecologist, USFWS. “Our ability to sustain waterfowl populations through harvest and habitat management depends on an understanding of the environmental factors that influence these populations annually, over continental scales.”

Within EAGLES, the Customized Online Aggregation & Summarization Tool for Environmental Rasters (COASTER) system allows users to visualize spatial and temporal patterns in environmental data sets. The system contains data that would take months to compile and weeks to analyze. It can process large data sets and facilitate cost-effective generation of customized environmental covariates for analysis.



COASTER can characterize ecosystem circumstances in a specific area of interest, such as a national park, by using real-time manipulations of 77 geospatial biophysical variables. As the project and partners demonstrated in 2012, such data allow wildlife managers, biologists, and land managers who use COASTER and other EAGLES tools to make their own ecosystem assessments and

examine the appropriate explanatory variables in species population models. A test of the system in 2012 showed it reduced the average processing time from six months to six weeks.



Supporting Users

“The design of the COASTER system was based on feedback from a number of federal biologists, including USFWS biologists and managers,” said Kurt Johnson, national climate change scientist, USFWS. “We wanted something that was free, on the Internet, in GIS-ready formats, and most importantly, a user friendly analysis tool set that provided access to enormously large data sets on changing environmental and habitat conditions.”

Over the course of the project, the team also integrated or created enabling data products to assist managers, applied researchers, and other users of the system. For instance, the team loaded temporal and spatial meteorological data on COASTER. The team created a 60-year climate data set at daily, 1-kilometer resolution for the contiguous United States. Derived from MODIS data, the project team also created a fractional surface water product, giving the percent of open surface water. Particularly supportive of continental waterfowl population models, this product covers most of North America at 500-kilometer resolution and provides estimates every eight days.

Beyond USFWS, potential end users of the system include the U.S. Forest Service, Bureau of Land Management, National Park Service, state fish and

wildlife departments, tribal governments, universities, and nongovernmental organizations focused on conservation.

During 2012 the project team conducted training sessions on its tools and products with tribal colleges, USFWS, and conservation agencies. The team and USFWS plan to conduct additional training in 2013, such as at conferences of conservation organizations, to help people employ EAGLES, COASTER, and all the tools to inform their decisions.

In 2013, the project will finalize and deliver its geospatial data and analytical tools to USFWS.

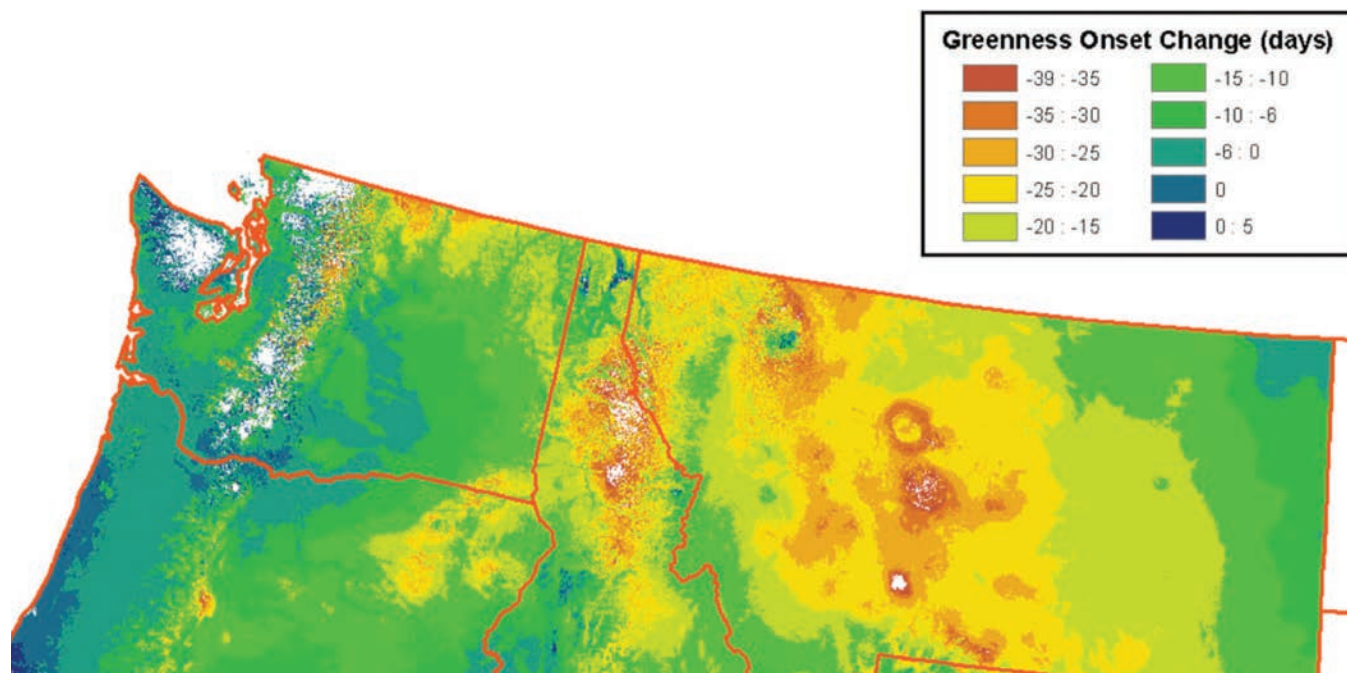
Robert (Bob) Crabtree leads this project: crabtree@yellowstoneresearch.org. To learn more about EAGLES tools, visit www.yellowstoneresearch.org/eagles.html.

Migrating Bison

Using the EAGLES system, the project created a means to generate estimates of annual forage production using MODIS vegetation data. Applying the forage estimates (along with estimates of the amount of water stored in snow) in models, the team predicted the seasonal migration of bison from Yellowstone National Park.

The team concluded that the significant variables for predicting bison movement were herd size, annual forage biomass, and changing snowpack. Wildlife managers can now better understand how bison decide to leave or stay in the park, depending on how hard it is for the bison to access forage through the snow as well as compete with each other.

P.J. White, chief of wildlife resources at Yellowstone, said: "The forage and snow estimates . . . were useful for predicting seasonal migrations by Yellowstone bison within and outside the park, and in improving collaborative policies with other federal, state, and tribal agencies to manage transboundary movements based on considerations of bison conservation, disease transmission to cattle, human safety, and property damage."



COASTER supports ecosystem assessments. This example shows the 55-year trend (1955–2009) in spring greenness onset in the Pacific Northwest and Northern Rockies.

Supporting and Improving Earthquake Preparation and Response



When a major earthquake strikes, emergency management agencies want accurate, up-to-date information to assess damage, threats to critical infrastructure, and potential aftershocks. An Applied Sciences project known as E-DECIDER (Earthquake Data Enhanced Cyber-Infrastructure for Disaster Evaluation and Response) developed decision support tools for emergency management using Earth science data.

In October 2012, the E-DECIDER team demonstrated many of its products and integrated them into state operations by participating in the California Earthquake Clearinghouse ShakeOut, an annual earthquake exercise. More than 9 million people participated in the associated preparedness drill.

ShakeOut posed a scenario of a magnitude 7.6 earthquake on the southern San Andreas fault. The E-DECIDER team provided data products to the exercise, including tilt maps (to measure changes in slope), synthetic interferograms (to identify surface deformations), and aftershock forecast maps (to indicate the likely location of additional smaller earthquakes). The team incorporated data from MODIS, *Landsat*, UAVSAR, and other sources into products that state and federal agencies can use to allocate response resources quickly and effectively in the event of an earthquake.

Identifying Changes

California Geological Survey (CGS) geologists used the team's radar imagery and viewing tool to identify areas of elevation change, which indicated locations of potential

damage. They disseminated the earthquake damage locations for field investigators to plan site visits.



"During the exercise, CGS geologists utilized the [E-DECIDER] imagery to help map landslides and other sites of hazardous ground deformation caused by the earthquake," said Chuck Real, supervising engineering geologist, CGS. "In urbanized areas, the imagery also served as damage proxy maps that in the aftermath of a real earthquake could help emergency responders choose safe locations for staging response and to optimize the distribution of emergency medical supplies, food, and other critical resources."

ShakeOut utilized the Unified Incident Command



and Decision Support (UICDS) middleware, which DHS developed for data sharing among emergency management agencies. The exercise included representatives from 12 organizations, such as the California Emergency Management Agency, California Department of Transportation, DHS, and USGS.

The exercise was an important opportunity for E-DECIDER to validate data products and support UICDS implementation. The project's stakeholders include disaster responders, emergency managers, and officials who would use E-DECIDER resources in the event of an earthquake disaster. The project team provides support to end users through Web and mobile interfaces. E-DECIDER is combining remote sensing and geodetic data and developing modeling and forecasting resources for short- and long-term decision making.

The California ShakeOut incorporated a NASA team's data products, enhancing future abilities of federal and state agencies to respond to earthquake disasters.

"E-DECIDER enriches our capabilities with a regional picture: a snapshot of regional effects, which helps in planning activities in the most critical areas," noted Anne Rosinski of CGS and chair, California Earthquake Clearinghouse. "The project supports our mission to share information . . . so that responders and specialists can best use their time and expertise in the field."

Addressing Hazards

An earthquake that strikes a heavily populated area can cause countless casualties and property damage. Federal and state authorities need to allocate resources and deploy everything from first responders to hazardous materials teams. Identifying areas with the greatest deformation and damage can inform decisions on where to focus emergency services. Deformation gradient information may pinpoint hazards to gas distribution, telecommunications, and power systems. In addition, assessing vertical change can be critical to identifying

areas with high likelihood of significant damage to if not failure of water supply, drainage, and sewer systems.

Exercise participants viewed the E-DECIDER team's modeled results in Google Earth (KML) format, including data overlaid on maps of Census and critical infrastructure information. DHS personnel were particularly interested in the maps, the aftershock forecast and tilt layers, and the possibility of identifying dams, bridges, and other damaged infrastructure sites. The team's contributions complemented the inputs of other participants.

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 "E-DECIDER's approach combines satellite imagery, GPS, and sophisticated computer models to quickly assess what communities and infrastructure are at the greatest risk following a major earthquake and will provide the emergency response community with potentially lifesaving knowledge shortly after the earthquake."

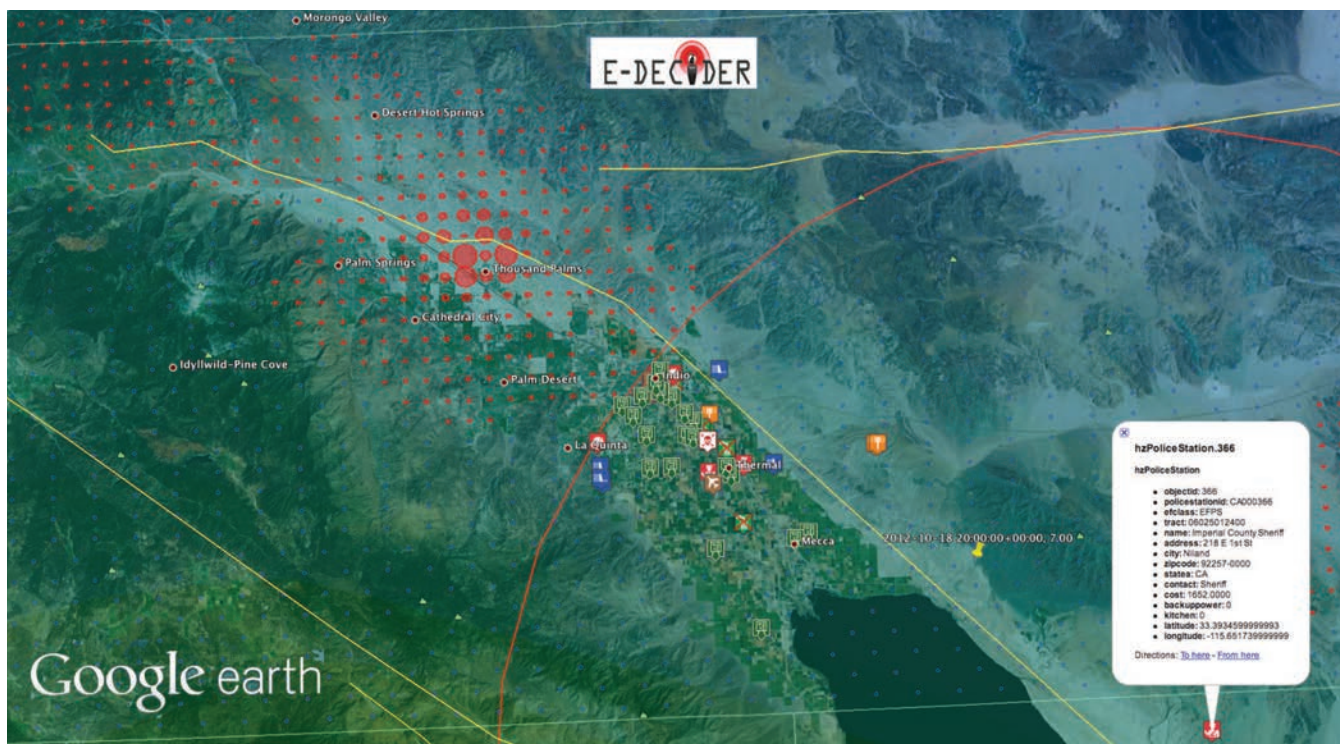
Gerald Bawden, U.S. Geological Survey

"The teamwork between the NASA JPL E-DECIDER team and the DHS UICDS team has produced an extraordinarily valuable improvement to the emergency response capabilities across the United States," said James W. Morentz, UICDS outreach director. "Quite simply, critical data on national infrastructure has become meaningful in the context of real emergencies."

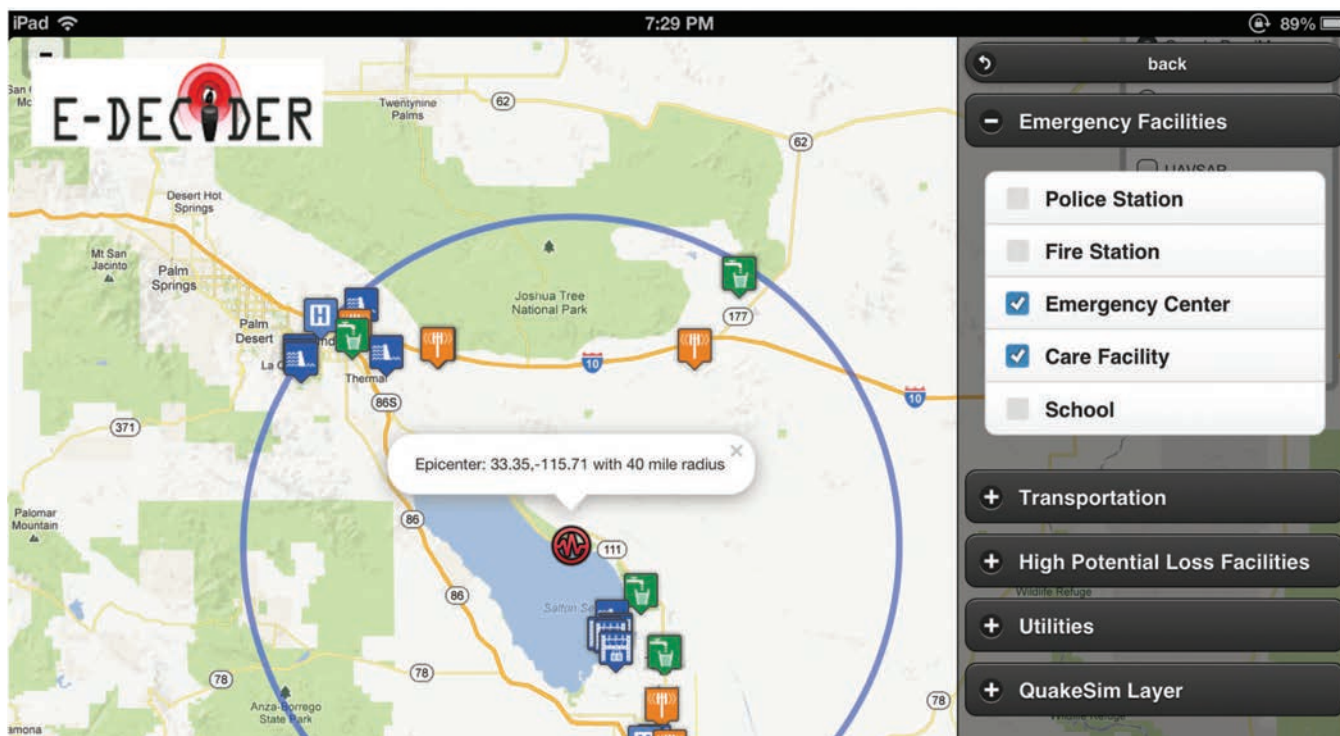
The project team is conducting workshops and meetings to better understand end users' needs and enlarge the end user audience. For instance, it held a meeting with DHS, USGS, and other stakeholders in November 2012. Discussions at the meeting led the team to make early 2013 plans for refining maps and further automating processes.

In 2013, the team will continue to improve its tools, collaborate with end users in workshops and training sessions, and deliver a final system. The system will offer advanced evaluation and response resources to the California Emergency Management Agency, California Seismic Safety Commission, FEMA, USGS, CGS, and other federal, state, and local agencies.

Maggi Glasscoe leads this project: margaret.t.glasscoe@jpl.nasa.gov. To learn more about E-DECIDER, visit <http://e-decider.org>.



The image incorporates tilt information, indicating where vertical changes in the surface have occurred, which could affect roadways as well as sewer and other water conveyances. Red dots indicate larger changes in tilt. Critical infrastructure that was potentially exposed to damage can be viewed by specifying an epicenter of radius and then listing the items of interest. The callout in the image shows a police station.



The E-DECIDER mobile interface utilizes the KML-generating service. This service allows emergency responders and decision makers to specify an epicenter and radius of interest to examine infrastructure that may have been exposed to the earthquake, helping them focus resources where they are most needed.

Upcoming in 2013



Applied Sciences has been tracking projects and monitoring progress on several projects that show potential for significant results. Here are three that we're especially watching to deliver results in 2013.

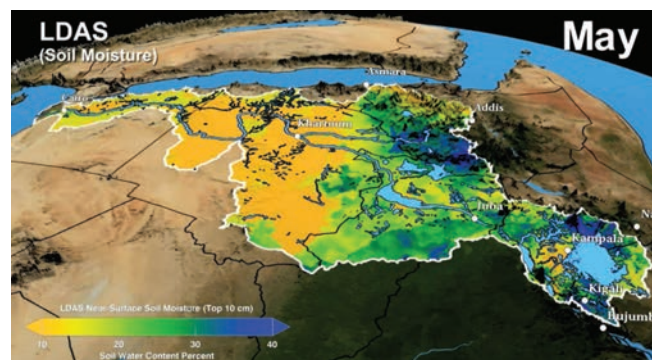
Advancing Flood Forecasting and Water Management in the Nile Region

Working with government agencies and nongovernmental organizations in Africa, a project is applying Earth observations and advanced modeling tools to enhance flood forecasting and water management in the Nile headwaters region.

More than 80 percent of the water in the Nile River originates in Ethiopia, and most of it comes from the Blue Nile. The Blue Nile region is reliant on agriculture and is susceptible to extremes of drought and heavy rain. Most of its annual precipitation falls within a four-month period (June to September), and the region has limited flood storage capabilities.

The project is working with the Eastern Nile Technical Regional Office (ENTRO), which is part of the Nile Basin Initiative, an intergovernmental organization for water resources development. Using *TRMM* data, ENTRO provides flood forecasts for the Eastern Nile Basin. Its forecasts on the likelihood, location, and timing of flooding inform disaster preparedness, such as moving livestock to higher ground, getting people out of harm's way, and mobilizing aid supplies.

The project achieved important milestones in 2012. The project team delivered a water balance analysis and data products to ENTRO. It also developed a Nile land data assimilation system, or LDAS, which incorporated land surface models and *TRMM* precipitation data to estimate hydrological states and fluxes. The team compared the estimates with *in situ* observations and evapotranspiration and moisture estimates obtained using USDA's Atmosphere-Land Exchange Inverse



The Nile LDAS merges satellite data with hydrologic models to estimate hydrological states and fluxes across the basin. This sample 2009 monthly average of near-surface soil moisture clearly shows the transition from humid zones in the south to deserts of the north, with transitional semi-arid zones that are marginal for crops and livestock.

“PHAM gives them the ability to take these satellite products and use them in their statistical analysis.”

Michael Hinton, Inter-American Tropical Tuna Commission

remote sensing technique. The team also mapped land use, applying MODIS data from *Terra* and *Aqua* to model vegetation and soil parameters.

In 2012, the project developed a partnership with the World Bank, which, based on irrigation development it has funded in the region, is interested in Blue Nile flows. The project team participated in a World Bank capacity building event at ENTRO, where it presented its work and discussed training opportunities for ENTRO staff.

Several projects are on track to deliver significant results in the coming year.

In 2013, the team will deliver data products to the World Bank, and it will complete the transfer of its tools to ENTRO and finalize end user training. ENTRO will have the ability to incorporate the project's tools fully into its decision support system and create a portal for public access online.

The project team expects to engage additional users in 2013, including the Ethiopian Environmental Protection Authority and the Ethiopian Ministry of Agriculture. The plan is to facilitate decision making through analyses of regional water balance, erosion, and climate change. In addition, based on an agreement formed in 2012 with the Ethiopian National Meteorological Agency, the team will compile precipitation and other data that can be used in drought monitoring, seasonal forecasts, and agro-meteorological analysis.

Ben Zaitchik leads this project: zaitchik@jhu.edu. To learn more about the Nile Basin Initiative and ENTRO, visit <http://nilebasin.org> and <http://nilebasin.org/newentro>.

Applying Research for Improved Fisheries Management

One project is working with the Inter-American Tropical Tuna Commission (IATTC) to develop and test applications of space-based oceanic environmental measurements to inform conservation and management of tuna and other marine resources in the eastern Pacific Ocean.

IATTC commissioners develop and issue fishery

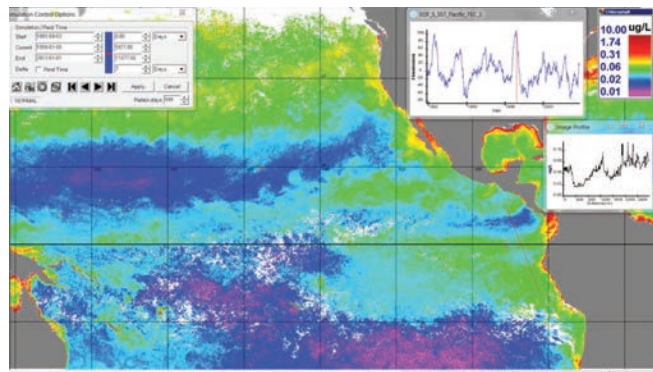
management resolutions and recommendations for the region. The scientists of IATTC annually provide the commissioners with stock assessments so that they can include in the management process the best available scientific information on the abundance of the tuna stocks. The assessment models that are the primary decision support tools for management decisions may, when they are available, include parameters that improve performance of the models by reducing variability in the results that arises from variation in ocean habitat and not from fish abundance.

The project team created the Pelagic Habitat Analysis Module (PHAM), a software package that produces data and statistical analyses as well as dynamic maps of habitat for pelagic ocean biota. PHAM integrates sea surface temperature and chlorophyll imagery from MODIS, ocean circulation models, fisheries survey data, tagging data, and other data products. Complementing catch and effort data (e.g., how much fishermen caught in how many days at sea), PHAM provides scientists and managers satellite data products and ocean modeling to examine and predict the habitat.



The PHAM habitat maps aid conventional stock assessments by providing a means to identify the environmental conditions (the habitat) and variability of commercial or threatened species. Adult tuna, for example, swim rapidly and cover large areas in their search for spawning and feeding grounds. The habitats at these grounds vary by tuna species. Parameters such as water temperature, circulation patterns, oxygen, and chlorophyll concentrations are important determinants of preferred habitat of each species. Fishery managers may use this kind of broader habitat-preference information to produce better estimates of stock abundance and to develop effective management actions, thereby improving their ability to identify stocks that could be at risk for overfishing and to take action to prevent overfishing from occurring.

“Some people find working with satellite and environmental data a big morass of intractability,” said Michael Hinton, IATTC senior scientist. “PHAM gives them the ability to take these satellite products and use them in their statistical analysis.”



PHAM image of chlorophyll at the midpoint of a 30-year (1981–2012) time series run. Warmer colors indicate higher concentrations (ug/L). Trends in an associated time series of SST and in chlorophyll on a user-defined transect appear in line-graph displays. PHAM runs on the EasyGIS system that provides the software tools to download, store, and analyze the broad range of fishery and oceanographic data needed to define fish habitat.

The project completed the design and implementation phases in 2012. IATTC received the fully operational software package as well as training from the project team. As a result of the training, IATTC scientists have used PHAM to improve identification of the habitat of skipjack, bigeye, and yellowfin tuna. The team also released PHAM Lite, a simplified version of the software.

In the coming year, the project team will continue to enhance the software. The team will also continue to conduct training to support PHAM's adoption in the IATTC stock assessment process, and to expand the end user community, which could take two to three years for full implementation.

Dale Kiefer leads this project: kiefer@dornsife.usc.edu. To learn more about the Pelagic Habitat Analysis Module, visit www.phamlite.com. Pages 81–82 describe a socioeconomic impact analysis of the PHAM project.

Enhancing Estimates of Water Supplies and Seasonal Availability

An Applied Sciences project is working with the California Department of Water Resources (CDWR) to assess applications of MODIS snow cover data to improve water supply forecasting.

Estimating the amount of water stored in snow (snow

water equivalent, or SWE) helps inform seasonal water availability. Typically, hydrologists measure mountain SWE at middle elevation locations using snow pillows, which are large bladders that measure the weight of the overlying snowpack. Such measures provide detailed information at point locations.

Together with CDWR, the project team is combining snow pillow data in the Sierra Nevada with satellite observations of snow-covered areas. The team developed a re-analysis model using MODIS snow cover observations to map the distribution of SWE at 500-meter resolution at the seasonal peak (March 1) to the end of the snowmelt season.

The project team also developed a real-time SWE product (beta version), which blends past years' MODIS-based spatial patterns of SWE with surface observations from snow pillows. In 2012, the team generated weekly SWE maps as well as weekly SWE reports by watershed and elevation band for the Sierra Nevada.

The project's data supplemented information CDWR used for forecasting water availability from snowmelt. “It is also useful to see how the estimated SWE compares to the SWE on our reports derived from directly observed data or pillows. . . . The comparison from one week to the next is handy because our forecasts are done weekly,” said Steve Nemeth, an engineer and water supply forecaster at CDWR.



In 2012, CDWR found the MODIS-based snow data, including the percentage of average peak SWE at various elevations, offered significant additional insight into early to late season runoff. For example, early in the season when snowmelt at lower elevations is not recorded by the mid-elevation snow pillows, CDWR has little snowpack information for forecasting early spring runoff. Similarly, late in the season when the middle-elevation snow pillows register zero SWE, CDWR has difficulty forecasting late season runoff.

CDWR is developing GIS-based, precipitation-runoff models for most Sierra Nevada basins. The department envisions bolstering the models with SWE data from the Applied Sciences project. “The idea is that we can better

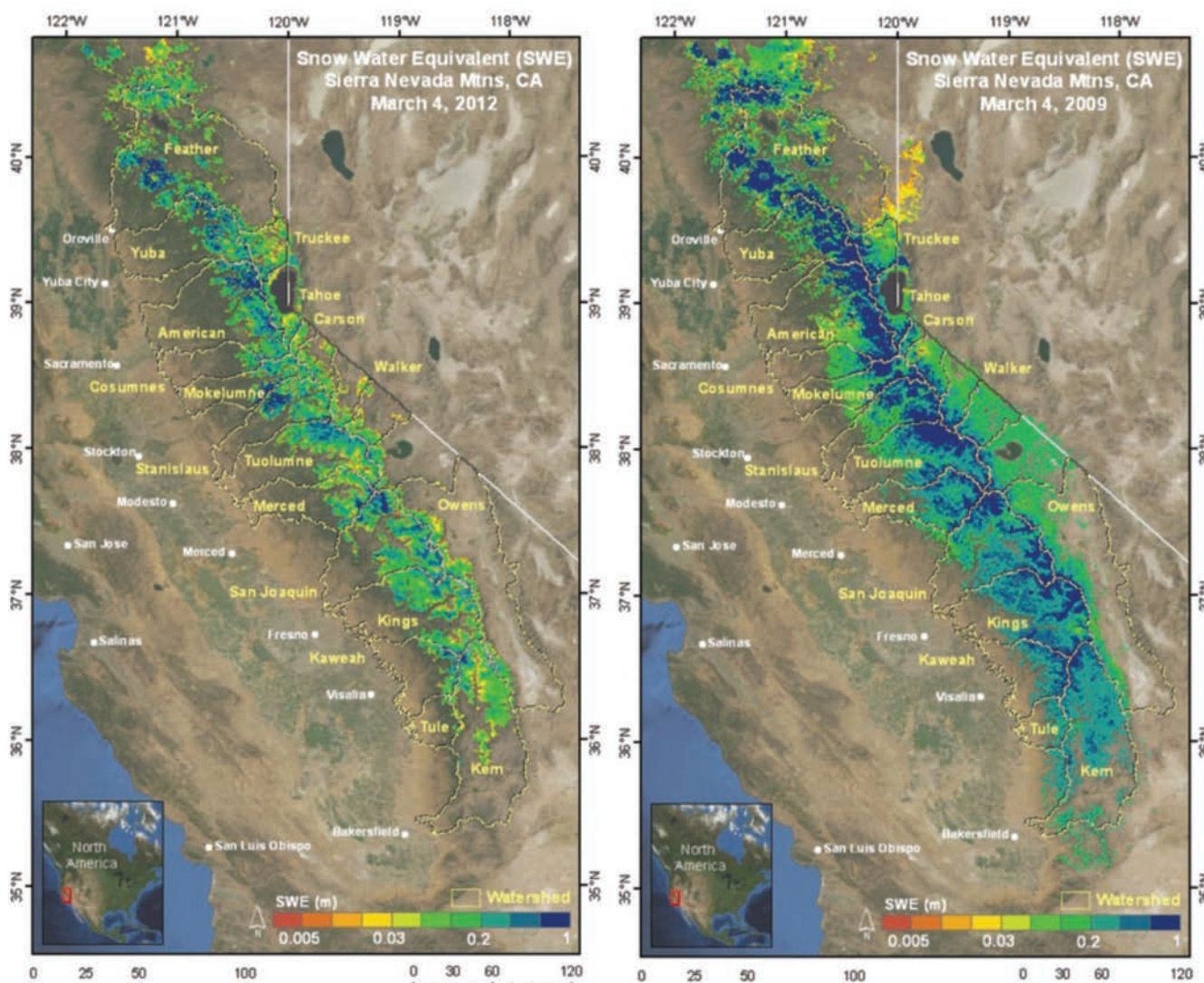
‘tune’ the physical parameters within the model using observed data,” said David Rizzardo, chief of CDWR snow surveys.

In 2013, the project will finalize adjustments to its data processing procedures based on CDWR feedback. CDWR and the team will continue to assess methods for augmenting the manual and automated systems for snow surveying to develop water forecasts. The team also plans to collaborate with organizations in the Colorado River Basin to examine similar applications there to inform flood and drought predictions, irrigation planning, and reservoir use.

Noah Molotch leads this project: noah.molotch@colorado.edu. To learn more about the project and related work, visit <http://instaar.colorado.edu/research/labs-groups/mountain-hydrology-group>.

“Your [NASA project team’s data product] gives us a clue to the snow above the highest instrument and the elevation at which there is no snow. . . . Knowing the snow where there is no instrument is handy to estimate whether or not we are near base flow. If your maps show that there is still snow up high, we can conclude that we are not yet at base flow.”

Steve Nemeth,
California Department of Water Resources



Maps of snow water equivalent in the Sierra Nevada, comparing conditions in 2012 (left) and 2009 (right).

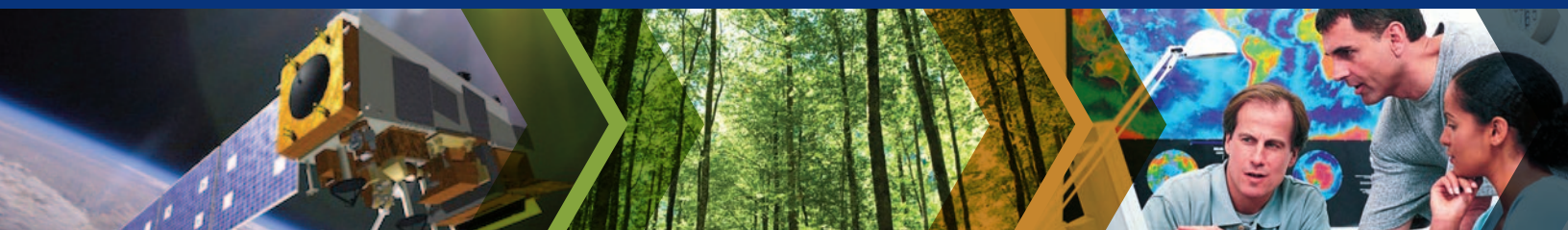
Selected Applied Sciences Program and Earth Science Applications-Related Events

- 4–6 ESIP Winter Meeting: Connections through Collaborations in the Data Life Cycle
- 18–20 National Council for Science and the Environment Conference: Environment and Security
- 19 Climate Policy Speaker: “The Psychology of Climate Change” (p. 90)
- 22–26 AMS Annual Meeting: Technology in Research and Operations
- 23 DEVELOP: Start of Spring Term; 63 participants and 18 projects (p. 61)
- 23–25 AMS Conference on Environment and Health
- 26 ESD: National Climate Assessment Indicators Workshop
- 1 ARSET: Start of Webinar Series on Remote Sensing and AQ Applications (p. 58)
- 7–8 ESD: LANCE User Working Group Meeting (with ESD Data Systems) on Near Real-time Data
- 16–17 *SMAP* Applications Focus Session for Arizona Urban Modeling Community (p. 83)
- 16–20 AAAS Annual Meeting
- 27–29 GEO: Essential Biodiversity Variables Workshop
- 29 Capacity Building: World Bank Workshop on Satellites for Water and Environment Management
- 29 Program: Kickoff for New Applications Area Associates (p. 75)
- 29 *SMAP* Applications Focus Session at Palo Verde Power Plant (p. 84)
- 1 GEO: Release of Earth Observations Priorities Report produced by Applied Sciences
- 6–8 NASA: Adaptation to Climate Risks Workshop for Johnson Space Center (p. 67)
- 12–15 ARSET: Training with LADCO and Affiliates on AQ Applications (p. 58)
- 13–15 Climate Prediction Applications Science Workshop: National Security Challenges
- 17 NASA: 10th Anniversary of *GRACE* Mission
- 19–23 ASPRS Annual Conference: Imaging and Geospatial Technologies—Into the Future
- 20 SERVIR: Project Review
- 21 Water Resources: Awards Announced for Applications Solicitation (p. 49)
- 22 DEVELOP: Start of Spring Virtual Poster Session at www.Earthzine.org (p. 61)
- 30 DEVELOP: End of Spring Term (p. 61)

January

February

March



July

August

September

- 5–6 GEO: GEO BON Steering Committee
- 10–11 GEO: Data Requirements Meeting for GEO-GLAM with CEOS (p. 94)
- 18–19 ESD: Meeting of Climate Adaptation Science Investigators (p. 67)
- 19 Program: Applications Areas and Capacity Building Review
- 20 SERVIR: Launch of ISERV Camera to ISS (p. 64)
- 23 NASA: 40th Anniversary of *Landsat* Satellites
- 23–27 Esri International User Conference
- 25 Disasters: Awards Announced for Applications Solicitation (p. 54)
- 25–27 GEO: Health and Environment Community of Practice Workshop (p. 93)
- 31 Climate Policy Speaker: “State of International Climate Change Negotiations” (p. 90)
- 8 NASA: Vietnamese Academy of Science and Technology Visit at NASA HQ
- 10 DEVELOP: End of Summer Term (p. 61)
- 12 Publication of *The Value of Information* (p. 89)
- 13 DEVELOP: Start of Summer Virtual Poster Session at www.Earthzine.org (p. 61)
- 21 NASA: URISA Announcement of NASA Induction into GIS Hall of Fame (p. 57)
- 22 ARSET: Completion of Five-week Advanced AQ Training Webinar Series
- 25–1 ISPRS Congress: Imaging a Sustainable Future
- 28 Earth Observation Forum: 50th Anniversary of International Symposia on Remote Sensing of Environment
- 29 DEVELOP: Mentor Bernard H. Eichold II Awarded NASA Exceptional Public Achievement Medal (p. 60)
- 10 DEVELOP: Start of Fall Term; 98 participants and 20 projects (p. 61)
- 13 DEVELOP: Winners of Summer Virtual Poster Session Announced (p. 61)
- 18–20 Health & AQ: Applications Team Meeting
- 18–20 Joint *SMAP* and *ICESat-2* Mission Applications Tutorial (p. 85)
- 19 Climate Policy Speaker Series: “Crowd-sourced Climate Change Reporting” (p. 90)
- 24 Program: Applications Areas and Capacity Building Review
- 27–28 Water Resources: Remote Sensing Workshop (p. 49)
- 30–4 URISA Annual Conference for GIS Professionals

- 1 SERVIR: Launch of Redesigned www.SERVIRGlobal.net (p. 64)
- 10 Applied Sciences Advisory Group Teleconference
- 11 Climate Policy Speaker: "Impacts of Climate Change and Urbanization on Future Building Performance" (p. 90)
- 12 First *ICESat-2* Applications Workshop (p. 84)
- 16 Program: Satellite Missions and Applications Review
- 17–19 Joint Agency Commercial Imagery Evaluation Workshop
- 25–27 Ecological Forecasting: Applications Area Team Meeting with ESD Color Research (p. 52)
- 27 Release of USGCRP 10-year Strategic Plan
- 27 DEVELOP: Spring Virtual Poster Session Winners Announced (p. 61)
- 30–4 GEO: Work Plan Symposium on Building Synergies in Tasks and Components
- 1–4 Water Resources: IISD Conference on the Water-Energy-Food Security Nexus
- 2 Release of National Research Council Report, *Earth Science and Applications from Space: A Midterm Assessment of NASA's Implementation of the Decadal Survey* (p. 87)
- 4 NASA: 10th Anniversary of *Aqua* Satellite
- 7–9 Program: External Assessment of Capacity Building Program Element
- 9 ARSET: Start of Five-week Webinar Series on Remote Sensing and AQ Applications
- 10 Climate Policy Speaker: "Climate and the Media" (p. 90)
- 17 Program: Applications Areas and Capacity Building Review
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- 22–24 Ecological Forecasting: USA National Phenology Network Council (p. 52)
- 4 DEVELOP: Start of Summer Term; 178 participants and 31 projects (p. 61)
- 5 Health & AQ: OECD Forum on Health (p. 50)
- 11–14 ARSET: Training on Remote Sensing and AQ Applications at Desert Research Institute (p. 58)
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- 13–15 Health & AQ: ACAST Meeting with Midwest AQ Managers (p. 51)
- 18 NASA: Announcement of CYGNSS Project in Earth Venture Mission Selection (p. 86)
- 19–20 ARSET: Training on Flood and Drought Applications at National Weather Center (p. 59)
- 20–22 Rio+20 Summit on Sustainable Development; SERVIR Presence (p. 65)
- 21–22 ESD: *Suomi NPP* Applications Workshop (p. 86)

April

May

June



October

November

December

- 9–10 Applied Sciences Advisory Group Meeting
- 12 Program: Satellite Missions and Applications Review (p. 74)
- 15–19 SERVIR: Summit and Partners Meeting
- 16–18 *HyspIRI* Science Workshop (p. 86)
- 17–18 Joint Mission Workshop for *SMAP*, *GPM*, *GRACE-FO*, and *SWOT*, and Hydrology Applications (p. 85)
- 21–24 Program: Panel at IEEE Global Humanitarian Technology Conference
- 22 Publication of *Environmental Tracking for Public Health Surveillance* (p. 88)
- 23 Health & AQ: Central States Air Resources Board Meeting
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- 29 Landfall of Hurricane Sandy; Disasters Area Organized NASA's Response (p. 53)
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- 15 Program: Applications Areas and Capacity Building Review
- 16 DEVELOP: End of Fall Term
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- 27 DEVELOP: Start of Fall Virtual Poster Session at www.Earthzine.org (p. 61)
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- 29–30 Health & AQ: ACAST Meeting at California Air Resources Board (p. 51)
- 30–1 GEO: GEOSS Water Strategy Workshop and Initiation of Water Plan
- 1 NASA: Release of NASA *Earth as Art* Book, e-Book, and App for iPad (p. 96)
- 3–5 Disasters: U.N. Crowdsourcing Mapping for Disaster Risk Management Meeting
- 3–6 GEO: GEO BON All Hands Meeting
- 3–7 AGU Fall Meeting
- 4 ARSET: Completion of Five-week Webinar Series on Earth Observations for Flood and Drought Applications
- 4 Health & AQ: ACAST Town Hall Meeting at AGU
- 5 *ICESat-2* Applications Town Hall Meeting at AGU
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- 6 NASA: Earth Science Town Hall Meeting at AGU
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Applications Areas and Capacity Building Activities

The Applied Sciences Program promotes applications of Earth observations to inform and enhance decision making in industry, government, and civil society. In 2012, the Program focused on four primary applications areas: Disasters, Ecological Forecasting, Health & Air Quality, and Water Resources.

Applied Sciences supports capacity building in the United States and abroad, particularly in developing countries, to improve capabilities in accessing and applying Earth observations. The Program supported four activities: Applied Remote Sensing Training, DEVELOP, the Gulf of Mexico Initiative, and SERVIR.

The Program continued to support several projects and initiatives related to climate assessments and adaptation.



Applications Areas



The Applied Sciences Program maintained four primary applications areas in 2012. The areas supported projects that focused on applying Earth observations to bolster disaster planning and response, enhance natural resource management, improve public health decision making, and advance the management of water resources. Applied Sciences also supported ad hoc activities in other topics, which may become formal applications areas in the future.

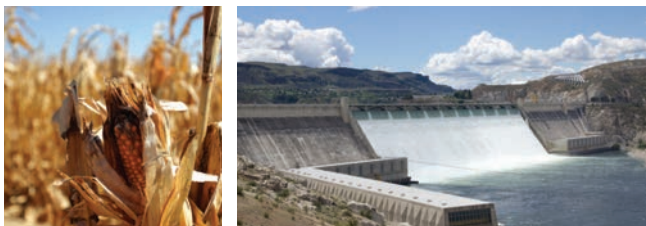
Water Resources

The Water Resources Applications area encourages the integration of Earth observations into management practices for the sustainable use of water. In 2012, Water Resources had 25 projects and feasibility studies in its portfolio. Projects address issues such as drought assessment, irrigation practices, watershed management, water quality, groundwater change, and climatic and ecological impacts on water resources.

One project focused on applying data from NASA, European Space Agency (ESA), and other satellites to produce a robust monitoring system of more than 180 lakes and reservoirs worldwide. The project supports the

USDA Foreign Agricultural Service (FAS) to assess irrigation issues and determine crop production estimates that serve a variety of trade and farming-related programs. In 2012, in response to U.S. national needs, this project began monitoring Afghanistan's Kajakai Reservoir, which is smaller than 100 square kilometers (62 square miles). The project thus demonstrated improved capabilities of *OSTM/Jason-2* over its predecessor satellites, opening up opportunities for FAS for other similar-sized targets.

A project involving coastal water quality standards informed decisions by EPA and Alabama and Florida agencies. The project applied data from MODIS and *Landsat*, historical data from SeaWiFS and ESA's *Envisat*, and field observations. The project's data products supported EPA's proposed rule establishing numeric nutrient criteria for estuarine and coastal waters of Florida. Also in 2012, the Florida Fish and Wildlife Commission incorporated the project's remote sensing data into a prototype decision support system for the rezoning of the Florida Keys National Marine Sanctuary.



Severe drought conditions affected significant portions of the United States and other parts of the globe in 2012. The Water Resources area continued its support of the U.S. Drought Monitor and USAID's Famine Early Warning System network. For example, for the USDA/NOAA-led U.S. Drought Monitor, NASA provided groundwater and soil moisture drought indicators of wet and dry conditions each week in 2012. The indicators are based on terrestrial water storage observations derived from *GRACE* satellite data and integrated with other observations, using a sophisticated numerical model of land surface water and energy processes.

Water Resources projects made substantial contributions to drought assessment, flood monitoring, and water management in the United States and abroad.

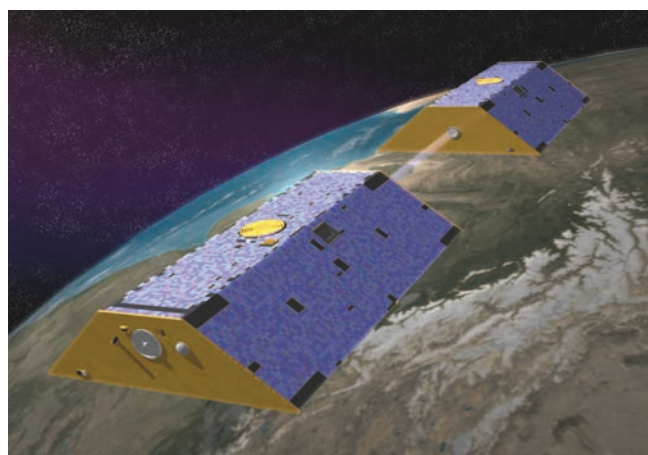
Water Resources selected 13 new projects under an open, competitive solicitation focused on drought prediction, assessment, adaptation, and mitigation. Using Applied Sciences' new approach to solicitations, the 13 projects began in 2012 as short-term feasibility studies of potential applications. One study is working with Cargill to examine the use of soil moisture data from ESA's *SMOS* and NASA's upcoming *SMAP* satellite to assess drought impacts on crop yields and improve decisions on crop management, commodity trading, and food security.



Addressing Emerging Issues

The Water Resources Applications area sponsored the Water-Energy-Food Security Conference in May 2012, together with the Global Water System Project and the International Institute for Sustainable Development. The conference addressed the water-energy-food nexus in preparation for the U.N. Conference on Sustainable Development (Rio+20). In addressing challenges for water management, such as climate and land use change,

the meeting covered topics including governance, Earth observations, bio-economic development, and transboundary river basins. As a result, attendees concluded that innovative polycentric governance models would be key to new partnerships necessary for water-energy-food security and the resilience necessary to deal with future uncertainties.

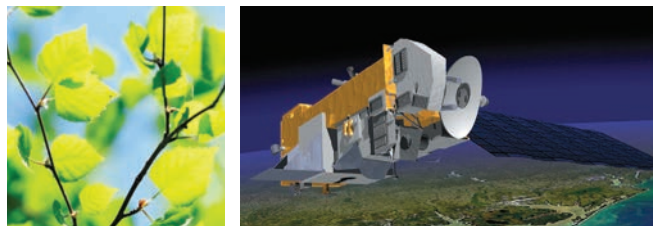


The applications area made significant efforts in 2012 to engage the water community, including more than a dozen events, workshops, and industry meetings. For example, NASA co-sponsored a September workshop with the Environmental Defense Fund, California Water Foundation, and Water Education Foundation. The event brought together more than 80 technical experts, academics, and water policy leaders to learn about the potential water management benefits of remote sensing. The workshop focused on California and the Colorado River Basin, where water scarcity is a serious issue. Participants learned about remote sensing technologies for snowpack monitoring, evapotranspiration measurement in water use accounting, groundwater elevation detection, and other applications.

In 2013, the Water Resources Applications area will evaluate the drought-related feasibility studies and select a subset to pursue as in-depth, multi-year applications projects. The area expects to participate substantially in the planned May 2013 Water for Food Global Conference hosted by the Daugherty Water for Food Institute at the University of Nebraska.

Health & Air Quality

The Health & Air Quality Applications area encourages the use of Earth observations in air quality management and public health, particularly involving environmental health and infectious diseases. The area includes effects of climate change on air quality and public health to support managers, policy makers, and people with health-related decision making. In 2012, the Health & Air Quality portfolio included 20 projects and feasibility studies along with the 19-member Air Quality Applied Sciences Team.



A health applications project to develop a repository of data specifically for decision making in malaria and meningitis control concluded in 2012. In collaboration with the International Research Institute for Climate and Society (IRI) at Columbia University, the project team created online resource “rooms” for information on malaria and meningitis. These rooms provide public health officials with dynamic maps and tools to create time series of disease status and relevant environmental factors. The maps and tools combine vegetation, land surface temperature, and other data products from MODIS and *Landsat*. The team also developed interfaces that link outputs from the repository to WHO and other public health platforms.

A project to improve the performance of air quality management decision support tools achieved significant milestones. The project focuses on tools used in the process for development and evaluation of emission controls under provisions of the U.S. Clean Air Act. In 2012, the project team incorporated MODIS aerosol and *Aura*/OMI ozone data in the Community Multiscale Air Quality model, which U.S. states use in their planning to meet air quality standards. EPA and the Texas Commission on Environmental Quality are partners on this project; the commission generously provided complementary funding.

In early 2012, CDC launched a Climate Change module within the National Environmental Public Health Tracking Network (www.cdc.gov/ephrtracking), a resource for the public, policy makers, and health professionals. Building on a partnership with the applications area, the new module uses an NLDAS-based maximum temperature

and maximum heat index. Understanding relationships between climate and health, officials can prepare for public health events and advise specific groups to take actions, such as during a heat wave.

Engaging Stakeholders

The applications area presented and led sessions at meetings of the American Thoracic Society, Central States Air Resources Agencies, AGU, and AMS. John Haynes, program manager, presented a lecture on applications of Earth observations for health and air quality in April at the Uniformed Services University of the Health Sciences, which is part of the Military Health System.

In June, the Organization for Economic Cooperation and Development (OECD) held a global forum on health hosted by the French space agency, CNES. This event was the fourth in a series of workshops on issues raised in the OECD report, “Future Global Shocks: Improving Risk Governance.” By invitation, Haynes spoke at this event, which discussed the capacity of technology (including remote sensing) to monitor and warn for global threats, including threats to health such as pandemics.

In a very productive year, Health & Air Quality projects delivered applications of *Terra*, *Aqua*, and *Aura* data and Earth science models for malaria, meningitis, heat waves, and air quality management.

In 2013, the Health & Air Quality Applications area plans to solicit proposals for feasibility studies and in-depth applications projects on innovative uses of Earth observations for infectious disease, environmental health, and air quality forecasting and planning.

The program will be involved in the second phase of ESD’s DISCOVER-AQ airborne field campaign, especially through ACAST. The program also plans to hold an ACAST meeting in June and its annual team meeting in September. In addition, it plans to expand its relationship with current and future relevant NASA satellite missions, such as the TEMPO instrument selected under Earth Venture in 2013 (see page 86).



To view the resources for meningitis and malaria control, visit <http://iridl.ideo.columbia.edu/maproom/Health>.

Connecting Science and Air Quality Management

The NASA Air Quality Applied Sciences Team (AQAST) connects air quality managers with atmospheric scientists and applications specialists to apply the latest knowledge and data. Team members conduct individual applied research projects and participate in ad hoc teams for rapid-response applications. AQAST meets twice a year to review progress and meet with managers from state, local, and regional air quality agencies to identify key needs for applications and specific opportunities to transfer their scientific knowledge.



AQAST held two team meetings in 2012. One meeting took place in June at the University of Wisconsin, Madison, addressing air quality issues in the upper Midwest. Representatives from the Lake Michigan Air Directors Consortium (LADCO), Wisconsin Department of Natural Resources, Southeast Michigan Air Quality Study Group, and EPA Region 5 presented key issues facing their organizations and locales. In addition, the meeting assisted Environment Canada in determining the growth of nitrogen dioxide emissions using satellite observations over the Alberta oil sands.

Team member Bryan Duncan reported on the dramatic decrease in sulfur dioxide and nitrogen dioxide emissions over the eastern United States during the past seven years as measured by *Aura*/OMI. AQAST member Greg Carmichael, University of Iowa, reported on his assistance in 2012 to Iowa City public health officials during a local landfill fire. He provided results from WRF air quality models to assist them in determining public health risks from the smoke plumes during weekend outdoor events.

AQAST also held a November 2012 meeting in Sacramento in partnership with the California Air Resources Board. Participants discussed current air quality management issues in California and western states, such as the need for central California to reduce emissions by 60 percent over the next several years to fulfill regulatory requirements. AQAST members identified opportunities to provide assistance regarding PM_{2.5} emissions, ozone emissions, modeling of complex terrain, and transboundary pollution (particularly from Asia and Mexico). AQAST member Ed Hyer, Naval Research Laboratory (NRL), announced the transition to ESD's LANCE near real-time system of the NRL MODIS Level 3 Aerosol Optical Depth product.

AQAST announced that January 2013 would see the launch of controlled and agriculture burn forecasting for Iowa in partnership with the Iowa Department of Public Health. AQAST plans to hold its first meeting of 2013 in June in the mid-Atlantic region.

To learn more about AQAST, visit the new website it launched in 2012, www.aqast.org.

Ecological Forecasting

The Ecological Forecasting Applications area promotes the use of Earth observations and models to analyze and forecast changes that affect ecosystems and to develop effective resource management strategies. Primary user communities are natural resource managers (both land and marine) and those involved in conservation and sustainable ecosystem management. In 2012, the Ecological Forecasting portfolio had 17 projects.

A project worked with NOAA to enhance Coral Reef Watch, a decision support tool using satellite observations to track water temperatures around coral reefs (<http://coralreefwatch.noaa.gov/satellite>). Extremely hot and cold temperatures threaten corals around the world, and temperature-related stress can lead to a loss of the ability of corals to photosynthesize their food. In



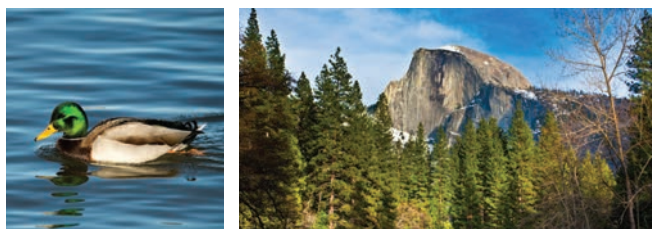
2012, the project team developed MODIS- and AVHRR-based heat and cold stress products (with cold stress a completely new product). The team also developed a 4-kilometer, AVHRR Pathfinder-based sea surface temperature climatology. These products help tell managers where serious impacts on coral reefs are likely

to occur and inform decisions on limits to activities on or around these important ecosystems.

Ecological Forecasting was very active in international efforts to use satellite observations in conservation, biodiversity, and ecosystem management.

A project focusing on river temperature forecasting and water management for the Sacramento River completed in 2012. Led by NOAA NMFS, the project delivered a system that allows water and fishery managers to minimize the downstream temperature effects of reservoir discharges on endangered salmon. Using TOPS and WRF models and data from MODIS, the system provides accurate temperature hindcasts, nowcasts, and forecasts on an interactive visualization site (<http://oceanview.pfeg.noaa.gov/RAFT>). Among the system's end users are the California Fish and Game Commission, U.S. Bureau of Reclamation, and USFWS. NOAA agreed to continue system enhancements and expansion.

Ecological Forecasting held its annual team meeting in 2012 in conjunction with ESD's Ocean Color Research team. At this meeting, Woody Turner, program manager, introduced the new Ecological Forecasting associates. In addition to reviewing projects' progress, a major topic of the meetings was to vet the Group on Earth Observations (GEO)-derived set of Essential Biodiversity Variables, including how they relate to needs and observations for natural resource management. The Ecological Forecasting Applications area leads ESD efforts related to the GEO Biodiversity Observation Network (GEO BON) and the EBVs (see page 94).

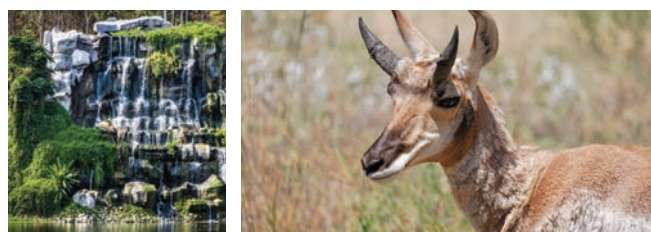


In 2012, Ecological Forecasting solicited proposals for feasibility studies of innovative uses of Earth observations and modeling to improve conservation and resource management in terrestrial, freshwater, and marine ecosystems. The solicitation requires the inclusion of crowdsourcing initiatives in the applications concepts. Proposals are due in 2013.

Leading Conservation Communities

The applications area participated in the advisory council

meeting of the USA National Phenology Network in May 2012. This network of government agencies, academia, and nonprofits promotes the development of tools that track phenology (periodic changes in plant and animal life cycles) to understand how changes in climate are affecting living systems. In recent years, natural resource managers have increased their use of satellite-based observations to track large-scale vegetation changes, such as annual cycles of greening up and browning down. At this meeting, attendees established a small team to explore how satellite imagery could be used with on-the-ground changes tracked by citizen scientists engaged in the Nature's Notebook project of the Network. The team plans to issue a report in 2013.



In July 2012, Ecological Forecasting participated in the annual meetings of the Society for Conservation Biology and the Society for Conservation GIS, which are two major groups in the global conservation community. Program representatives and investigators highlighted the role of Earth observations in conservation work and activities sponsored by the Applied Sciences Program, including grant opportunities for innovative Earth science applications.

An international workshop in Germany in October 2012, Satellite Remote Sensing for Biodiversity Research and Conservation Applications, examined remote sensing needs of the global conservation community. The Committee on Earth Observation Satellites (CEOS) sponsored the workshop with the German space agency, DLR. The conservation community increasingly uses satellite observations to monitor changes in land cover, ocean surface conditions, and climate. Workshop participants discussed key satellite observations for biodiversity research and conservation, identifying continuity of the *Landsat* and MODIS time series, hyperspectral imagery, and 3-D imagery from LiDAR sensors as crucial needs. Participants also discussed the importance of free and openly available satellite imagery, especially to applied conservation in developing countries, and drafted an article on the importance of free and openly available data policies for publication in 2013.

The applications area sponsored a workshop planned for January 2013 with the Wildlife Conservation Society to identify the top 10 conservation questions that could be

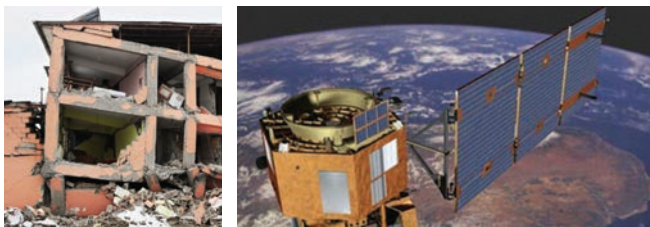
addressed through satellite remote sensing. In addition, the area is planning to hold its annual team meeting in April 2013 jointly with the ESD Biodiversity Research program. As a follow-up to the January “questions” workshop, this meeting plans to have sessions to identify the observation and technology priorities for terrestrial and marine research and applications.

Disasters

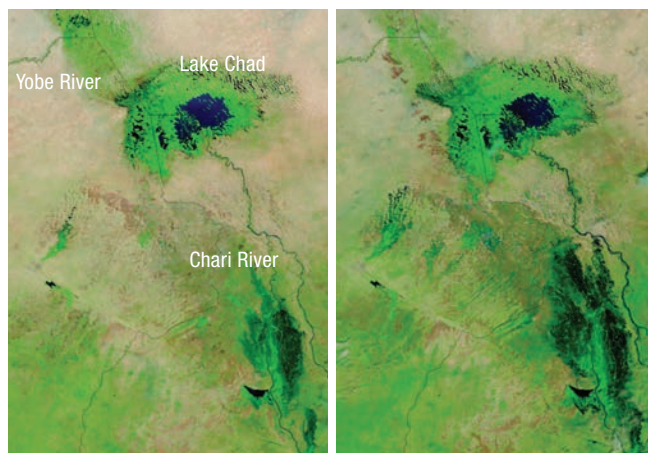
The Disasters Applications area promotes the use of Earth observations to improve prediction, preparation, response, and recovery from natural and technological disasters. In 2012, the Disasters area portfolio had projects with regional to global reach in earthquakes, flooding, and other topics. The Disasters area also organized NASA's contributions to disaster response, such as wildfires in the United States, Typhoon Bopha in the Philippines, and flooding in Pakistan.

The applications area led NASA's contributions to responses to 18 disasters, including Hurricane Sandy, and projects supported disaster preparations, such as one in which the state of California invested funds for follow-on activities.

In 2012, the Disasters area made significant progress, and past investments hit milestones toward increasing disaster preparedness and mitigation. One project in the Sacramento–San Joaquin River Delta validated use of NASA's UAVSAR airborne radar for rapidly detecting seeps or structural damage in levees. This novel use of radar remote sensing identifies subtle changes in levee conditions before catastrophic failure. Due to the value of this project to California water resources and emergency management, the state committed additional funding for UAVSAR flights through 2014. DHS and USACE also began exploring the application of the project's outcomes (see pages 13–15).



The E-DECIDER project continued integrating *Landsat*, *MODIS*, and other data into earthquake disaster forecasting, response, and recovery (see pages 37–39). The project team participated in a major California earthquake response



Flooding in central Africa on October 19, 2012 (right) compared with October 26, 2011 (left) from *Terra*/MODIS. In the 2012 image, the Yobe and Chari rivers are swollen, water is higher along Lake Chad, and a floodwater lake stretches from northern Cameroon into Chad.

exercise, integrating its decision support tools into state emergency management operations. The project also supported the implementation of DHS middleware for data sharing among emergency management organizations. The project concludes in 2013 and will look to transition its evaluation and response resources to FEMA, USGS, and other federal, state, and local agencies.

Assisting Disaster Response

In addition to applications development, the Disasters Applications area led NASA's response to disasters that occurred in 2012. NASA supported the response to 18 events in 2012, making Earth observations and satellite imagery available to support emergency managers and disaster responders.

NASA aided the response to major wildfires in four U.S. states and Australia in 2012. Information products from *MODIS*, *ASTER*, and *EO-1* supported assessments of fire perimeters and other analyses. Through ESD's LANCE near real-time data system, NASA provided the products for incident command teams managing wildfires in High Park and Waldo Canyon, Colorado, as well as wildfires across California, Nevada, and New Mexico.

In addition, NASA provided *MODIS* and *TRMM* data and imagery to assist damage assessment for and in response to Tropical Storm Debby in the Gulf of Mexico, and Tropical Storm Isaac in the Caribbean. For flooding in Pakistan and Russia, NASA delivered near real-time flooding products derived from *MODIS* data in collaboration with the Dartmouth Flood Observatory.

For Hurricane Sandy, NASA provided observations in the hours, days, and weeks after the disaster. Based on data



derived from *Suomi NPP*/VIIRS, NASA provided images to FEMA, USGS, and DoD to help identify neighborhoods in the region without power. Disaster managers integrated the VIIRS data into their own processes to help gauge power restoration in support of recovery efforts and distribution of relief supplies and equipment. NASA also provided total rainfall maps from *TRMM*, flood maps derived from MODIS, and images from *Terra*/ASTER and *EO-1* (see pages 21–23).

Roughly a month later, Typhoon Bopha hit the Philippines. Using data and imagery from *TRMM*, *Terra* (ASTER, MODIS), *Aqua* (AIRS, MODIS), and *Suomi NPP*/VIIRS, NASA delivered products through the International Charter on Space and Major Disasters to support disaster mitigation, such as multi-satellite precipitation analysis and flood maps. Moreover, NASA used the techniques on power outage assessments developed for Hurricane Sandy to support NASA contributions to the Bopha disaster response.

The Disasters area selected 17 new projects under an open, competitive solicitation focused on flooding, earthquakes, volcanic effluent, and landslides. Using Applied Sciences' new approach to solicitations, the 17 projects began in 2012 as short-term feasibility studies of potential applications. For example, one study is examining the use of MODIS and future sensors to aid flood inundation predictions for the U.N. World Food Program and its decisions on flood damage assessment, food assistance, and transportation access.

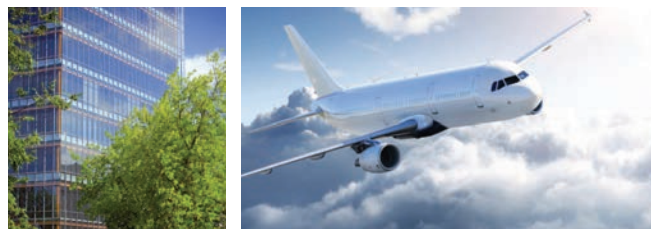
The Disasters Applications area was involved with CEOS in 2012 to develop a plan for disaster risk and management. In December, NASA hosted a meeting of the CEOS Disasters team, which prepared initial materials for a 2013–2015 disaster management “road map.” The team intends to present its findings and recommendations at the CEOS Strategic Implementation Team meeting in March 2013.

In 2012, the Disasters area participated in the U.N.-hosted Experts Meeting on Crowdsourcing Mapping for Disaster Risk Management and Emergency Response. The meeting examined crowdsourcing approaches already in practice as well as the use of space-based data as inputs for disaster response, such as abilities to crowdsourcing disaster assessment based on satellite data. Francis Lindsay, Disasters Applications program manager, presented information on E-DECIDER's efforts to use “citizen seismology” in the improvement of post-earthquake damage assessment maps.

In 2013, the Disasters area will select a subset of feasibility studies begun in 2012 to pursue as in-depth, multi-year applications projects. It will continue to support CEOS efforts for international coordination on disasters, and it will continue to lead NASA's support and response to disasters in the United States and abroad.

Other Applications

In addition to the four primary applications areas summarized in this report, the Applied Sciences Program supports ad hoc activities in five others: Agriculture, Climate, Energy, Oceans, and Weather. Applied Sciences also pursues applications of Earth observations on topics that cut across the areas, such as wildfires.



Activities in the Weather area focus primarily on aviation safety. A project with the National Center for Atmospheric Research (NCAR) developed a prototype system that helps improve the safety of commercial aviation. Combining satellite data and computer weather models, the system provides eight-hour forecasts, updated every three hours, of potentially dangerous atmospheric conditions. The forecasts are for pilots, air traffic controllers, and others involved in transoceanic flights to aid in avoiding major storms over remote ocean regions.

NCAR created the system with MIT's Lincoln Laboratory, NRL, and the University of Wisconsin, Madison. The team verified its initial forecasts using a variety of NASA data, including *TRMM* observations. The forecasts from the prototype system can significantly enhance the data available to pilots, supporting decisions on whether to

detour hundreds of kilometers around potentially stormy areas with severe weather and hazardous conditions. In 2013, NCAR will continue to test, modify, and improve the forecasts. To view outputs from the prototype system, visit <http://go.nasa.gov/W0doRu>.



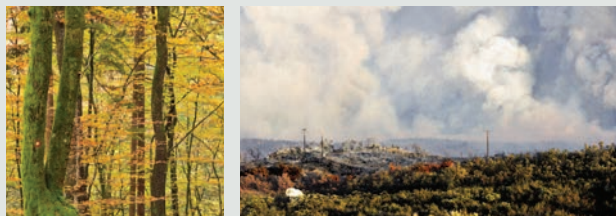
An energy-related project with NCAR tested an innovative technique to improve wind energy estimates at proposed wind farm sites using NASA global re-analysis data from MERRA. (Based on a variety of surface- and satellite-based measurements, MERRA provides a three-dimensional global record of weather every six hours since 1979.) To aid in the site-selection process, the project developed a more accurate and repeatable estimate of the long-term record of winds at discrete locations. The new method can closely approximate the accuracy of the current industry wind resource

assessment approach (a 365-day sample) with only a 180-day sample, reducing computational time and expenses. The team also initiated a socioeconomic impact analysis of the project and its newly developed technique, presenting preliminary results at the AGU Fall Meeting in December 2012.

A project with the National Renewable Energy Laboratory (NREL) made progress in developing a satellite-based mapping tool to depict solar radiation levels globally. The project team—a collaboration of NASA, NREL, NOAA National Climatic Data Center, and the University of Albany—expects that the improved global long-term, high resolution data set will enhance several NREL tools, including the National Solar Radiation Database. In 2012, the team tested its algorithm for multiple surface sites and evaluated performance across data from several satellites, such as *GOES-8-12*, *Meteosat-5-9*, and *MTSAT-1R*, in the nearly 30-year record. In 2013, the team will finalize testing, develop the production system in concert with NREL and work to produce long test data sets, and begin the process of transferring the production system to NREL for operations.

Wildland Fires

Applied Sciences started 17 projects from a request for proposals focused on wildland fires. The projects apply Earth observations and models to inform land management strategies, reduce fire risk, and enhance post-fire recovery.



Fire is an issue that cuts across Earth system science and touches on aspects of many applications themes. In 2012, Applied Sciences reviewed project proposals addressing the application of Earth observations and models to wildland fire management, especially the pre-fire and post-fire stages. The solicitation

focused on interdisciplinary issues related to wildland fires in support of management strategies, business practices, and policy analysis and decisions. Proposals had to span two or more of the Program's applications areas, and they had to be framed around practitioners' challenges.

These projects will follow the Program's new approach of starting with feasibility studies and then, after a year or so, selecting a subset to pursue as in-depth applications projects. The Program received 47 proposals, and it selected 17 for awards, totaling approximately \$2.7 million for the first stage, feasibility studies. The projects commenced in late 2012.

The projects use Earth observations and models to address fuel loads, fuel treatment planning, risk assessment, air quality, insect infestations, environmental remediation, burned area rehabilitation, and other topics in land management.

Early Warnings of Forest Threats Using Earth Observations

The U.S. Forest Service (USFS) established forest threat assessment centers to give early warnings of environmental threats to public and private forests, informing and advancing resource management decisions. Threats such as weather patterns, defoliating insects, droughts, and wildfires occur nationwide and affect forest health. The centers provide science-based decision support tools for policy formulation and land management.

In March 2012, USFS officially launched ForWarn, a forest threat early warning system for the conterminous United States. USFS collaborated with NASA Stennis Space Center (SSC), USGS, and the DOE Oak Ridge National Laboratory to develop ForWarn, which applies satellite-based change recognition and tracking.



"We are excited to unveil ForWarn and its Forest Change Assessment Viewer, intuitive products that use advanced technology to provide a current look at forest changes and help focus on-the-ground response efforts," said William Hargrove, USFS Eastern Forest Environmental Threat Assessment Center. "Our goal is to help natural resource managers, scientists, and other decision makers better identify, understand, and react to environmental disturbances."

The system uses Earth science data from the MODIS sensors onboard *Terra* and *Aqua* to assess vegetation health and evaluate for environmental stress. In particular, the system uses Normalized Difference Vegetation Index products (see the NDVI callout on page 30). These NDVI products enable managers to rapidly identify forest and wildland changes and respond to threats, allowing them to deploy the necessary resources when and where they are needed most.

ForWarn builds on traditional methods of using hand-sketched maps drawn by spotters flying in light aircraft to locate and assess forest disturbances. Where

sketch map reports were available as frequently as once a year, ForWarn produces new forest disturbance maps every eight days. The system also allows targeting of disturbance alerts to specific users. For example, USFS can selectively alert entomologists to insect disturbances and plant pathologists to forest diseases, whereas forest owners and managers might receive all alerts for their forests.

"ForWarn epitomizes the type of product envisioned when the threat assessment centers were created," added Danny Lee, director of the Eastern Threat Center. "This tool literally puts space-age technology into the hands of forest resource professionals."

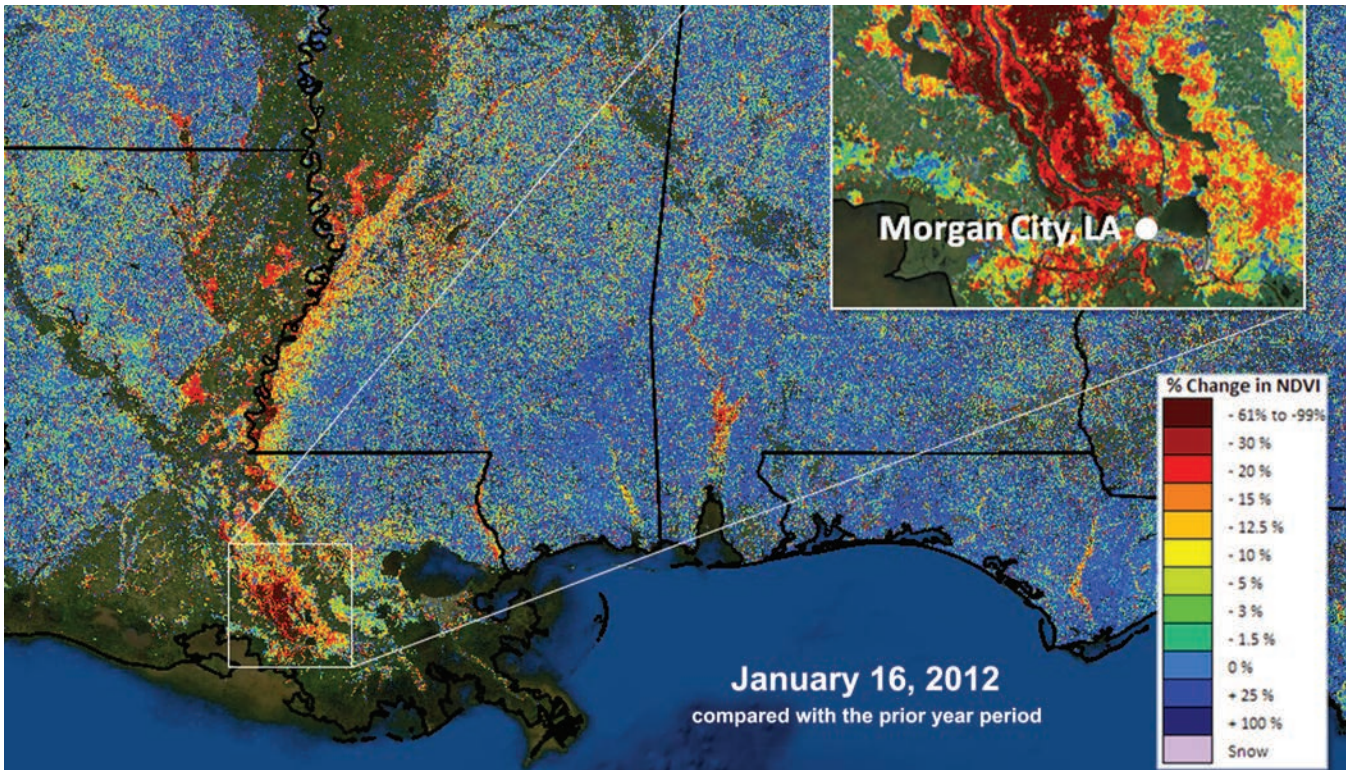
The four-agency team received the 2012 USFS Southern Research Station Director's Award for Excellence in Science Delivery. Also, late in 2012, the Federal Laboratory Consortium for Technology Transfer (FLC) announced that the ForWarn team would receive the 2013 FLC National Interagency Partnership Award and the 2013 FLC Southeast Region Interagency Partnership Award.

Under a Space Act agreement with USFS, SSC and its Applied Science and Technology Project Office (ASTPO) led NASA's participation and contributions. SSC uses ForWarn to identify threats to forests in the 138,500 acres of acoustic buffer zone around the rocket propulsion test stands and forested areas adjacent to the center.

"Forest health specialists across the country can now view current nationwide forest disturbance monitoring products, refreshed and posted to ForWarn's online Forest Change Assessment Viewer every eight days," said Joe Spruce, SSC project scientist.

With further enhancements in the works, ForWarn users can expect new and faster Early Detect products in 2013 to see earlier signs of forest disturbances. ForWarn will include a more automated forest disturbance recognition capability. Through a free subscription service, ForWarn will also issue alerts via email, phone messages, RSS feeds, Facebook, and Twitter.

William Graham leads this project: william.d.graham@nasa.gov. To learn more about ForWarn, visit <http://forwarn.forestthreats.org>. To learn more about SSC ASTPO, visit <http://science.community.nasa.gov>.



The Atchafalaya Basin's forests thrive with seasonal flooding, yet high water normally occurs in the spring there. In January 2012, unusually high water levels inundated wetlands and forests along and near the Mississippi River Basin. In this NDVI image from *Terra/Aqua* (MODIS), floodwaters appear to decrease existing vegetation, as water masks low-lying plant cover. According to USGS, river discharge at Morgan City, Louisiana, was 145,000 cubic feet/second on January 16, 2012, compared with 84,000 cubic feet/second the prior year.

Leading the Geospatial Community



In October 2012, the Urban and Regional Information Systems Association inducted NASA into the URISA GIS Hall of Fame.

This honor put NASA in the select company of just 13

individuals and five other organizations representing the most esteemed leaders of the geospatial community. URISA is a nonprofit association of professionals using GIS and other information technologies to solve challenges facing regional, state, provincial, and local government agencies.

The GIS Hall of Fame recognizes organizations and individuals with a record of contributing to the advancement of the geospatial industry. URISA inducted NASA along with Natural Resources Canada, Statistics Canada, the U.S. Census Bureau, and USGS. URISA described NASA as a "leader in the development and use of remote sensing data and tools, and the evolution of GIS data and applications for a wide range of public and private sector organizations."

"NASA is honored by this recognition from a leader in the use of geospatial data and tools across sectors. This honor is truly a tribute to the many people who design and operate the Earth-observing satellite missions, process and deliver the data, and analyze the measurements to benefit all humankind."

Michael Freilich, NASA ESD Director



To learn more about the URISA GIS Hall of Fame, visit www.urisa.org/hall_of_fame.

Capacity Building Activities



In 2012, the Applied Sciences Program supported four capacity building activities: Applied Remote Sensing Training, DEVELOP, the Gulf of Mexico Initiative, and SERVIR. These elements build capabilities to extend the application of Earth observations and benefit people.

Applied Remote Sensing Training

Applied Remote Sensing Training (ARSET) provides professional training in remote sensing and the application of Earth observations. In 2012, ARSET provided professional workshops in air quality and water resources, working directly with state, federal, and tribal agencies as well as the private sector to develop and conduct both in-person and online courses.



The courses train practitioners how to access, visualize, and apply Earth science data to inform decisions.

ARSET expanded its online courses in 2012, and it more than doubled the number of online and in-person participants from 166 in 2011 to 350 in 2012. Overall, ARSET conducted a total of 10 online and in-person courses. Eight courses were on air quality and two were

on water resources, covering uses of flooding tools and precipitation products.

ARSET had an outstanding year, with a record number of participants and several “firsts” in course development.

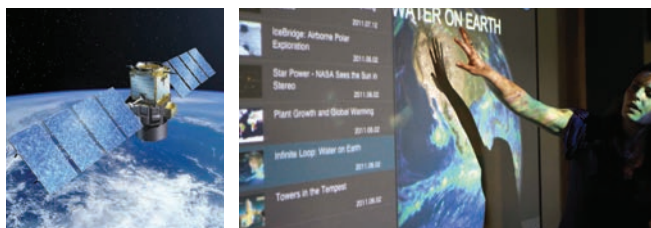
Air Quality

For the first time, online webinars were a prerequisite for in-person, air quality courses. These webinars occurred weekly for four to five weeks, providing background for the hands-on exercises conducted during the subsequent in-person training. The in-person sessions employed tailored case studies that demonstrated uses of Earth observations for the specific environmental management topics of interest to course attendees. ARSET held a hands-on training in March for LADCO member states, one in June for the Desert Research Institute (DRI), and one in October with environmental professionals at Environment Canada. ARSET held five-week online courses preceding each of these.

The program also offered its first advanced-level course online in 2012, addressing special topics in air quality remote sensing. A five-week course in July and August

covered a step-by-step methodology for using aerosol and carbon monoxide observations from MODIS and *Aqua*/AIRS to analyze air pollution due to fires. The course focus was the 2012 summer season wildfires in Colorado, Utah, and Montana and their effect on receptor sites in Iowa and Illinois. More than 50 individuals from 29 different government agencies, universities, and organizations participated in the course. It had attendees from six past ARSET in-person courses, including LADCO, DRI, and the California Air Resources Board.

In 2012, ARSET played a key role in facilitating interactions between ACAST and regulators from state air quality agencies in the United States. ACAST team members participated in ARSET training activities, where they had opportunities to share their research and tools with the air quality managers. At the request of course participants, ARSET organized a NASA session in October at the Central States Air Resource Agencies' annual meeting that featured presentations on ACAST projects.



Water Resources

In June, the National Weather Center at the University of Oklahoma, Norman, hosted an in-person ARSET course for water resources managers. This training addressed flood analysis using *TRMM* and *MERRA* products. The course included case studies specific to drought and flooding in Oklahoma using *TRMM* rainfall, *AIRS* and *MODIS* cloud data, *NLDAS* soil moisture, and *MERRA* wind and humidity products. Participants learned how to access, visualize, and analyze Earth observations to detect inter-annual rainfall variability and associated effects on large-scale soil moisture and evapotranspiration over Oklahoma. Among the participating organizations were the Oklahoma Water Resources Board, Oklahoma Department of Environmental Quality, Chickasaw Nation, USGS, University of Oklahoma Center for Spatial Analysis, and Association of Central Oklahoma Governments.

Evaluating the Program

ARSET began a formal evaluation process in 2012 to help assess progress to date and inform future directions. Interviews with ARSET participants from the past three years revealed that ARSET helped inform many organizations' executives of the scope of applications of Earth science data. End users reported benefits to their professional development, such as research and data collaboration projects formed as a result of ARSET training. The trainings also enabled them to articulate topics of interest for subsequent ARSET courses.



Most notably, the trainings catalyzed their use of Earth observations and remote sensing products. One air quality manager stated, "Our upper management was not very familiar with that aspect [of air quality remote sensing] and they were pretty impressed by the end of the presentation, that there is something out there we could get easily and use. From there, it was very helpful that they would allow us to do these things. Everything went smoothly from there."

In a five-week, online training late in 2012, ARSET reached 65 end users from across the world on applications of Earth observations to flooding, hydrologic modeling, and droughts. It was the first online ARSET course for water resources managers. Participants included people from Belize, Jamaica, Bolivia, and SERVIR hubs in East Africa and the Hindu Kush-Himalayan region. Several USAID and NOAA representatives who were engaged in capacity building participated. The sessions also contributed to U.S.-World Bank remote sensing efforts by enabling the participation

of 15 World Bank staff and partners in Africa and the Middle East. Case studies covered uses of decision support tools and data sets in the United States, South America, East Africa, and Southeast Asia.

Looking Ahead

In addition to air quality and water courses, ARSET plans an increased focus in 2013 on courses for disaster applications, especially tools for flood potential monitoring. ARSET also plans to offer courses on the application of NASA snow products to water resources management in the western United States. ARSET plans to develop training modules on land products, and it plans to complete a trainer's manual, which will provide guidance on ways to communicate Earth science research within a capacity building framework.

To learn more about ARSET, visit <http://airquality.gsfc.nasa.gov> and <http://water.gsfc.nasa.gov>.



A 2012 *Earthzine* article describes ARSET: www.earthzine.org/2012/10/03/nasas-arset-training-program-from-the-classroom-to-real-world-satellite-applications.

DEVELOP

DEVELOP is a national capacity building program in which young professionals gain hands-on experience with satellite remote sensing. The participants apply Earth observations to real-world issues facing state and local governments. These projects increase the understanding of partners' decision support needs and identify potential applications projects for Applied Sciences to pursue.



In teams on specific projects, the participants work under the guidance of science advisors from NASA and partner organizations. The young professionals deliver and communicate their results to broad audiences and leaders in government, academia, and industry. Overall, DEVELOP promotes a high-tech workforce and expands the network of organizations and individuals benefiting from Earth observations.



The past year was very productive and successful for DEVELOP, with 339 people working on 69 projects—about 30 percent increases over records set in 2011. In the geographic focus of the projects and the origin of the participants, DEVELOP encompassed 46 U.S. states, which was its broadest reach ever.

Excellence in Mentorship

Bernard Eichold II, a science mentor at the DEVELOP center with the Mobile County Health Department in Alabama, received NASA's Exceptional Public Achievement Medal in 2012. NASA praised Dr. Eichold for his outstanding achievements over more than a decade in engaging young professionals to broaden the use of Earth observations for community education and societal benefit.

Extending Globally

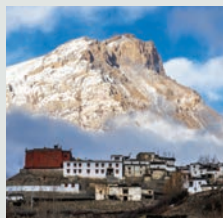
The program also had participants from 10 countries and some internationally focused projects. For example, in a NASA collaboration with the Embassy of Rwanda, four Rwandan Presidential scholars studying in the United States participated in the DEVELOP summer term as well as two in the fall term.

DEVELOP expanded to 14 centers in 2012, adding two new locations and opening opportunities for projects, participants, and partnerships in their regions. One new center hosted by IRI is in Palisades, New York. Another new center is in Kathmandu, Nepal, hosted by the International Center for Integrated Mountain Development (ICIMOD); this center is a DEVELOP partnership with Applied Sciences' SERVIR program and is the second international center.

Among the 2012 projects, one DEVELOP team worked with St. Bernard Parish, Louisiana, and focused on the degradation of coastal forests and wetlands, which provide a natural protective barrier on the Gulf Coast. The team at NASA Stennis Space Center applied

DEVELOP Virtual Poster Session Winners

DEVELOP and *Earthzine* continued their partnership in 2012 for virtual poster sessions. The project teams in each DEVELOP term produced abstracts and related videos highlighting NASA Earth observation capabilities relative to environmental issues and concerns for enhanced policy making and decision making. Panels of judges evaluated the materials on use of Earth observations, overall product, discussion, creativity, and decision support. Here are the winners and runners-up for each term.



Spring 2012: 18 Projects, 63 DEVELOPERS

Winner: “Seeing Through the Texas Smoke Using NASA Earth Observations”

K. Hall, M. Boyd, and J. Carpenter

Team from DEVELOP–Langley Research Center

Runner-up: NASA Radar Assessments of Water Extent along River Levees”

Team from DEVELOP–Jet Propulsion Laboratory

Summer 2012: 31 Projects, 178 DEVELOPERS

Winner: “Where Have All the Cypress Gone? Mapping Restoration Sites in Louisiana”

R. Reahard, M. Ewing, E. Strong, C. Kelly, and M. Arguelles

Team from DEVELOP–Stennis Space Center

Runner-up: “The Peat Burns On: Making Sense of North Carolina Wildfires”

Team from DEVELOP–Langley Research Center

Fall 2012: 20 Projects, 98 DEVELOPERS

Winner: “Climate Change Vulnerability in Nepal Using NASA EOS”

Binita KC, T. Rael, T. Webb, E. Crook, C. Herdy, E. Shrestha, F. Tuladhar, and L. Thapa

Joint team from DEVELOP–Marshall Space Flight Center and DEVELOP–Nepal

Runner-up: Four teams tied for runner-up. See the *Earthzine* site for the list.

Applied Sciences and DEVELOP wish to thank *Earthzine* and Esri for providing the winners and runners-up with recognition and prizes.

To learn more about the virtual poster sessions, visit www.earthzine.org/vps-archive.

Terra/ASTER, *Landsat*, *EO-1*/Hyperion, and other Earth observations to create a methodology for monitoring and delineating suitable planting sites for bottomland hardwood trees. The team’s methodology set the planting strategy for the 2013 season, showing how Earth observations can advance restoration efforts.

Multiple projects addressed environmental concerns in Rwanda, including ones to assess long-term deforestation, reforestation dynamics, and agricultural practices. For instance, one project team applied *Landsat* and *Terra* data to evaluate farming practices and deforestation effects on erosion and resulting soil degradation. The team offered an efficient and sustainable methodology for monitoring progress and efficacy of reforestation efforts and land management.

Throughout 2012, the young professionals presented valuable research results and met potential new project end users at more than 45 science and policy conferences. DEVELOP participants discussed their work with officials at key government events, such as those of

DEVELOP had a record-breaking year in participants, projects, and global scope in 2012.

the Council of State Governments and Southern Growth Policies Board. They discussed their work with scientists at events like the AGU Fall Meeting. DEVELOP also produced more than 15 individual articles in publications such as *Directions Magazine*, *Earthzine*, *Earth Observer*, and *Bay Area Automated Mapping Association Journal*.

In 2012, DEVELOP continued its partnership with *Earthzine* to conduct three “virtual poster sessions” and project video contests (see callout). DEVELOP produced 65 project videos in 2012—almost every project in this record-setting year. DEVELOP launched a new website with increased interactive features like live feeds and a video wall. The program also launched D-POD, DEVELOP’s podcast series hosted on the new website featuring interviews with project team leads.

In August, DEVELOP held a major event at NASA Headquarters in Washington, D.C., as a close-out of its summer term. More than 100 DEVELOP participants exhibited their work through presentations and posters. In 2012, DEVELOP introduced “flash talks,” in which teams gave fast-paced, five-minute summaries of their projects. The program webcast the entire event live, and some DEVELOP teams presented via video conferencing. The “DEVELOPers” gained useful presentation experience while informing the Headquarters community about practical applications of Earth observations. Senior NASA officials, including NASA Administrator Charles Bolden, attended the event and interacted with the teams. In addition, officials from the Embassy of Rwanda were special guests at the event.

DEVELOP plans to expand the number of participants in 2013, primarily by enlarging the ranks in its spring and fall terms. The program will establish a new center at the University of Georgia, and it plans to increase collaboration with academia for enhanced science advising and recruiting.

To learn more about DEVELOP, visit <http://develop.larc.nasa.gov>.

Gulf of Mexico Initiative

The Gulf of Mexico Initiative (GOMI) promotes the use of Earth observations to help local, state, and federal leaders in the Gulf region make informed decisions, establish effective policies, and respond to crises. GOMI focuses on regional priorities defined by the Gulf of Mexico Alliance (GOMA), a collaboration of Alabama, Florida, Louisiana, Mississippi, Texas, and 13 federal agencies to enhance the ecological and economic health of the Gulf region.



In 2012, GOMI had 44 active projects spanning the northern Gulf of Mexico and the southeastern United States. One project at Texas A&M University, Galveston, created a system that, for the first time, predicts *Sargassum* seaweed landings on Texas beaches. The *Sargassum* Early Advisory System (SEAS) uses *Landsat* data, Navy HYCOM ocean circulation model outputs,

and NOAA wind data. The system started in January 2012, and five Texas coastal managers had adopted this decision support tool by year's end to better plan their resources instead of simply reacting to unanticipated events. “The ability to know how much *Sargassum* is offshore has never been available before,” said Reuben Trevino, coastal resources manager, City of South Padre Island. “[SEAS] has really improved our ability to prepare . . . [for] what is headed in our direction.”

GOMI projects applied Earth observations and modeling to improve decisions on conservation, water management, and other important issues in the region.

Another project used UAVSAR-derived soil moisture and other data to improve levee management along the Mississippi River. In 2012, the project team built and demonstrated to the Mississippi Levee Board a tool that uses the data and machine learning algorithms to monitor the condition of levees. By identifying damage or threats to levees, the tool enables more efficient monitoring and inspection of the thousands of miles of levees that protect riverside communities. DHS provided some funding for this project, and USACE is evaluating the tool for its use.

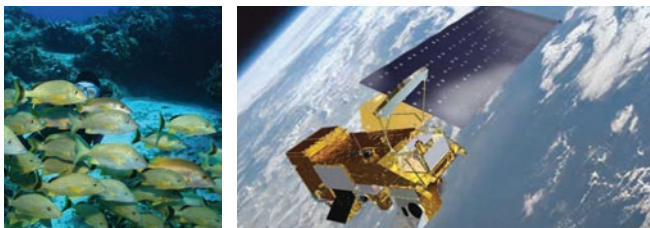
In January 2013, GOMI plans to hold a workshop in New Orleans to feature the results of the dozens of projects focused on applications of Earth observations to support the Gulf region. The projects address topics of priority for GOMA as well as applications themes such as water resources, disasters, ecosystems, and health.

Improving Data Access and Use

GOMI builds capacity in the Gulf region on how to access and use geospatial data and tools. In May 2012, GOMI worked with Google Inc. to hold a seminar that demonstrated Google geospatial tools for Gulf-related topics for novice and advanced users. The seminar, held at NASA Stennis Space Center in Mississippi, had more than 85 participants from 25 organizations. Participants included managers, IT professionals, scientists, engineers, and others representing industry, nonprofits, academia, and federal and state agencies. Google engineers familiarized the audience with the mapping and analytical capabilities of widely used, freely available tools such as Google Earth, Maps, and Fusion Tables. They also shared expert tips to solve common data analysis problems and improve analytical performance.

Broadening Efforts

At the 2012 AGU Fall Meeting, GOMI organized sessions on remote sensing ocean and coastal applications. The sessions examined topics such as ocean surface oil slick detection using MODIS and SAR inputs, detecting suspended sediments using *Landsat* and MODIS data, and analyzing algal blooms with data and imagery from *Aqua* and *Jason-2*. These projects provide information for coastal officials seeking to protect water quality for fisheries and beaches, support coastal and wetland conservation, and much more.



In addition to project and industry activities, GOMI builds capacity by supporting regional organizations around the Gulf. For example, in a partnership with the Alabama Department of Conservation and Natural Resources, Mobile Bay National Estuary Program, and NOAA, a project provided the first up-to-date assessment of land use practices in the Mobile Bay region in decades. The project team utilized MODIS and *Landsat* imagery to provide accurate assessments of the growth of urban areas along the coast of Mobile Bay, as well as changing land use practices over three decades. The team also provided data on impervious cover, which directly affects water quality in the bay, and on habitat stability, which is particularly important for sensitive, critical habitats such as wetlands. In 2012 the Mobile Bay National Estuary Program integrated the project's results into its overall conservation and management plan.

In 2013, GOMI will organize and host sessions at the Gulf of Mexico Oil Spill and Ecosystem Science Conference in New Orleans at the end of January. GOMI also plans to represent NASA at the GOMA All Hands Meeting in June.

To learn more about GOMI, visit <http://GulfOfMexicoInitiative.nasa.gov>.

SERVIR

SERVIR is a NASA–USAID joint venture that integrates satellite observations, ground-based data, and forecasting models to help developing countries address environmental challenges. SERVIR supports managers, educators, scientists, media outlets, and officials with

information to improve their decisions and actions. Using Earth observations, SERVIR helps organizations and people with water resources management, public health, disaster response, climate change, biodiversity conservation, agricultural development, and more. SERVIR has regional hubs in East Africa, the Hindu Kush–Himalayan region, and Central America. Additional hubs are under development.

Regional SERVIR hubs include the Regional Center for Mapping of Resources for Development in Nairobi, Kenya, and ICIMOD in Katmandu, Nepal. A Mesoamerican hub operated under the auspices of SERVIR from 2004 to 2011 at the Water Center for the Humid Tropics of Latin America and the Caribbean, or CATHALAC, in Panama. It now operates independently, while continuing to tap SERVIR data and applications.

Expanding Services

SERVIR made significant progress in building capacity with Earth science applications during 2012. For example, SERVIR trained officials on the implementation of a hydrologic modeling tool known as CREST, short for Coupled Routing and Excess Storage. CREST integrates data from *TRMM* and local rainfall measurements, taking into account evaporation, soil porosity, elevation, and other factors to produce stream-flow forecasts. This capability is important to anticipate flooding locations, support farming practices, and identify potential agricultural deficits.

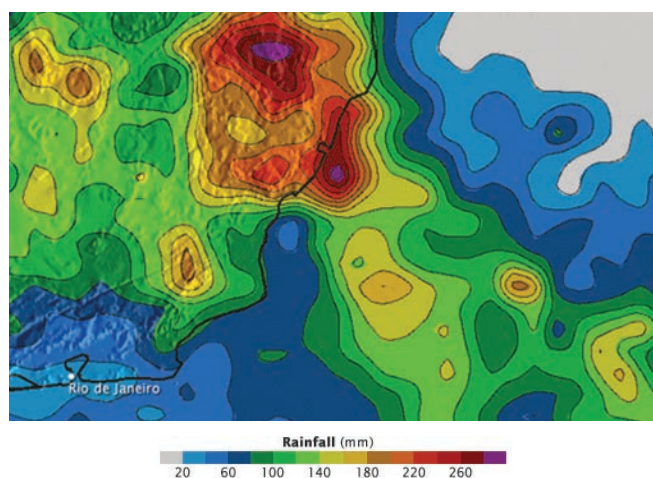


In April, SERVIR–Africa hosted hydrologists from 11 East African countries as well as Bhutan and Nepal for a CREST training workshop in Kenya. As a result, SERVIR began working directly with several of the participating countries based on requests for follow-on training or expanded operations of the CREST model in managing critical watersheds.

In collaboration with the Kenyan Meteorological Department, SERVIR–Africa expanded the CREST model in 2012 to include hydrologic forecasting. The Kenyan Department of Water Resources Management began using the associated data sets in identifying potential flooded areas several hours in advance, enabling officials to issue timely flood warnings. SERVIR also created a flood

mapping tool that enables users to visualize the extent of flood damage on key rivers. In 2013, SERVIR plans to incorporate flood alerts into its mobile text-alert system.

With the Rwandan Natural Resources Authority, SERVIR held a workshop in Kigali, Rwanda. Participants learned to use the CREST model to estimate flows for important catchments. For example, attendees from Rwanda's Integrated Water Resources Management Department and Rwanda's Meteorological Services learned how to use the modeled stream-flow to predict the probability of flooding along river networks in the lower catchment areas. Rwandan district hydrologists started to incorporate CREST into their routine stream-flow modeling, helping them visualize hydrological information on a website displaying all hydrological monitoring stations and variations of water levels at each station.



Depiction of heavy rainfall in southeastern Brazil, based on *TRMM* observations, December 30, 2011–January 6, 2012.

The My Community Our Earth (MyCOE)/SERVIR initiative began in 2012. MyCOE offers applied research fellowships to build regional capacity for using geography and geographic information sciences. With training from SERVIR in GIS, remote sensing, GPS, and spatial analysis techniques, the fellows address issues related to agriculture, climate change, and food security. USAID supports MyCOE/SERVIR, which the Association of American Geographers implements in cooperation with SERVIR hubs.

Eighteen people began as MyCOE/SERVIR fellows in East Africa in 2012. At a kickoff event in Nairobi for the first round of MyCOE/SERVIR, participants from the Democratic Republic of the Congo, Ethiopia, Kenya, Malawi, Rwanda, South Africa, Sudan, Tanzania, and Uganda received hands-on instruction across the range of services that SERVIR offers. MyCOE/SERVIR kicks off

in the Himalaya region in early 2013 and will have 15 fellows.

In a banner year, SERVIR helped people in developing countries make effective decisions by providing Earth observations and predictive models.

In 2012, SERVIR formed a new, competitively selected SERVIR Applied Sciences Team. This 11-member team of applied researchers broadens the scientific and applications base for the SERVIR hubs and regions in which they operate. Team members work on individual applications projects; they also serve on ad hoc sub-teams for special needs that arise. For instance, one project will apply data from *TRMM*, *EO-1*, *Radarsat-2*, and the upcoming *Global Precipitation Measurement (GPM)* satellite along with LIS model outputs to support predictions of landslides. Another will apply MODIS products, SRTM data, and DINAMICA landscape model outputs to help East African countries assess forest carbon stocks and achieve cost-effective, sustainable management of forests. Serving key needs in SERVIR regions, the team will advance developing countries' uses of these Earth observations and support U.S. international development interests.

In 2012, SERVIR launched a redesigned website, www.SERVIRGlobal.net. The new design improved search capabilities and access to geospatial data, information products, stories of successful applications, and services from SERVIR's hubs and partners. The new design introduced an Interactive Mapper tool that allows people to select Earth observations data sets and other information, display them on a base map, and manipulate them for analysis.



Building Collaborations

In July, NASA sent to the International Space Station (ISS) an automated camera system, which was developed with the SERVIR team. This ISS SERVIR Environmental Research and Visualization (ISERV) system consists of a commercial camera, telescope, and pointing mechanism to acquire images of the Earth's surface as the space

station passes over them. As a proof of concept, this tool can provide images that complement those from NASA's suite of Earth-observing satellites to help with disaster assessments and environmental response. After installation and system checks, NASA expects to begin using ISERV in early 2013. In October, the ISERV team received the NASA Silver Achievement Medal.

In 2012, NASA and USAID hosted the first SERVIR summit in Huntsville, Alabama. The event brought together team members from the SERVIR hubs and the coordination office as well as program leaders from USAID and NASA. Attendees discussed the status of their projects, exchanged information, and began developing plans for more projects.

In 2013, SERVIR expects that the launch of *Landsat 8* will aid applications in all the regions. In addition to another SERVIR summit, NASA and USAID program leadership plan to hold a sustainability workshop in the



The launch of ISERV aboard a Japan Aerospace Exploration Agency transfer vehicle, July 20, 2012, southern Japan.

spring to discuss future pathways and priorities for the SERVIR partnership.

To learn more about SERVIR, visit www.SERVIRGlobal.net.

Tackling Global Water Challenges

On World Water Day (March 22), NASA joined in the actions to form the U.S. Water Partnership (USWP). Deputy Administrator Lori Garver represented NASA during the inaugural event at the U.S. Department of State. USWP has more than 40 members, including foundations, corporations, government agencies, academic institutions, and nongovernmental organizations. It brings together and mobilizes U.S. resources to address water challenges around the world, especially in developing countries.

NASA's focus is on providing remote sensing-based solutions to global and regional water issues. NASA is contributing results from its portfolio of basic and applied research, Earth observation products, and modeling capabilities.

Applied Sciences organized ESD and NASA support of USWP throughout 2012. Nancy Searby, Capacity Building program manager, participated in the USWP formation event in March. Dan Irwin, SERVIR director, spoke at a major USWP event in June as part of the U.S. presence at the U.N. Conference on Sustainable Development in Rio de Janeiro. In September, Searby and others participated in an expert panel on water

security. Hosted by the United Nations, USWP, Skoll Global Threats Fund, and U.N. Development Program, the event defined water security including challenges and potential tools.

NASA, through ESD, participates in the Virtual User Advisory Board for the USWP Web portal, which provides U.S. water data and information to tackle water challenges worldwide. Together with USWP, NASA started to facilitate the use of NASA products in the World Resources Institute's Aqueduct water risk mapping tool (<http://aqueduct.wri.org>). The tool allows governments, corporations, and other users to identify water risks and opportunities worldwide. In 2013, water experts from NASA, the Skoll Global Threats Fund, and World Resources Institute plan to hold a series of meetings and activities to help address water issues in South Asia.



To learn more about USWP, visit <http://uswaterpartnership.org>.

Enhancing NASA's Climate Resilience and National Assessments



Applied Sciences continued its support of NASA Centers' climate risk adaptation planning and NASA's contributions to the 2013 National Climate Assessment.

NASA's Earth Science Division continued to be very active in 2012 in the application of scientific knowledge and modeling capabilities for climate change risk assessment and adaptation planning. ESD's Applied Sciences and Research & Analysis Programs continued to support efforts across NASA on climate risk resiliency at NASA Centers, together leading NASA's contributions to National Climate Assessments. ESD also continued its productive, ongoing collaboration with the NASA Office of Strategic Infrastructure (OSI), which manages the stewardship of NASA facilities.



Johnson Space Center

Using NASA Earth Science at NASA

ESD initiated the Climate Adaptation Science Investigators (CASI) work group in 2010 to investigate

climate risks at NASA Centers. In collaboration with OSI, the work group assists in the development of climate change adaptation strategies for NASA as a whole as well as at individual Centers. NASA Earth scientists partner with Centers' institutional stewards to address climate risks to operations, physical and biological assets, and personnel as part of master planning. Overall, these efforts support NASA's implementation of Executive Order 13514, which directs each federal agency to "evaluate agency climate-change risks and vulnerabilities to manage the effects of climate change on the agency's operations and mission in both the short and long term."

In 2012, ESD extended the first phase of the CASI work group involving eight Centers (ARC, DFRC, GSFC, JPL, KSC, LaRC, MSFC, and SSC), and added three additional Centers and Facilities (GRC, JSC, and WFF). In late 2012, ESD requested proposals from NASA Centers for CASI's second phase in FY 2013–FY 2015; ESD planned to announce selections by February 2013.

Based on the early successes of CASI, ESD also broadened the effort to include scientists outside NASA. In 2012, Research & Analysis selected and initiated seven peer-reviewed projects from an open solicitation, "Impacts of Climate Variability and Change on NASA Centers and Facilities."

The CASI work group, led by Cynthia Rosenzweig and Radley Horton of GISS, met in July 2012 to review progress and advance CASI products. Horton presented the GISS-developed downscaled climate projections for each NASA Center, including the associated uncertainties. Four CASI teams working on multi-Center products presented information on data products and techniques for CASI members and Center managers regarding energy, ecosystem modeling, hydrodynamic modeling, and a vulnerabilities matrix. For example, the energy team presented a RETScreen product that can support Centers' building design and efficient energy use in light of a changing climate and changing heating and cooling demands. Horton discussed how tailored climate data—specifically daily minimum and maximum temperature projections—are being provided to the energy team to support its high temporal resolution data needs.

At the meeting, one round of breakout sessions focused on CASI themes of energy, ecosystems, and surge modeling. A second round focused on regions—coastal, arid, and temperate—to address vulnerability and cross-Center interactions. Among the outcomes of the meeting, the CASI work group decided to use the latest CMIP5 climate model projections being developed in support of the IPCC Fifth Assessment Report. During the meeting, each CASI member met directly with the CASI leadership and OSI representatives to discuss future center interactions. In 2012, the CASI work group developed an article about its activities and hopes to publish it in a 2013 issue of the *Bulletin of the American Meteorological Society*.

Recognizing a Climate Adaptation Leader

In December, *Nature* named NASA Earth science researcher and CASI co-lead Cynthia Rosenzweig as one of “10 people who mattered” in 2012. Rosenzweig is very active in ESD's partnership with NASA's Office of Strategic Infrastructure and a sponsored investigator by both ESD's Applied Sciences and Research & Analysis programs. To learn more about her career and role as climate adaptation advocate for New York City, visit www.nature.com/news/366-days-nature-s-10-1.11997.

Climate Risks and Resiliency at NASA Centers

In March, NASA held a workshop in Houston to examine climate risks and adaptation strategies for Johnson Space Center and the surrounding Houston–Galveston region. JSC is home to NASA's Mission Control Center, astronaut training, and human spaceflight research. Around 100 people participated, including representatives from the Texas Air National Guard, Texas Water Development Board, City of Houston, General Services Administration, U.S. Postal Service, U.S. Army, Entergy Corporation, and Houston–Galveston Area Council. Attendees discussed the likelihood and consequences of climate impacts on infrastructure, natural resources, and communities. The key climate hazards in the region involve overall increased temperatures, sea level rise, and precipitation changes. For instance, sea level rise can exacerbate storm surge effects and lead to more frequent flooding of key transportation routes, limiting employees' access to the Center.



In September, NASA held a workshop in southern Mississippi to examine climate risks and resiliency at NASA Stennis Space Center and the surrounding communities. SSC is NASA's largest rocket engine test facility, and it has seven test stands. Participants included representatives from the Mississippi Power Company, Mississippi Department of Environmental Quality, U.S. Army, CDC, Pratt & Whitney Rocketdyne, Habitat for Humanity, and Southern Mississippi Planning and Development District. A key climate risk is sea level rise and the vulnerabilities it presents in storm surge and saltwater flooding to the Center, communities, and sound-buffering forests surrounding the test stands. Following the workshop, SSC decided to address built system upgrades first with an elevation survey of critical buildings to be initiated in early 2013.

In November, NASA held a workshop in the Delmarva Peninsula to examine climate risks and adaptation

strategies for the Wallops Flight Facility and Eastern Shore of Virginia. WFF is primarily a rocket launch site to support orbital and suborbital launches for science and exploration missions. Five partner organizations convened the workshop to coordinate efforts to develop adaptation strategies and research on impacts of climate change; the partners were WFF, the Accomack–Northampton Planning District Commission, Marine Science Consortium, Nature Conservancy, and USFWS. Workshop participants discussed coordinated adaptation strategies for the short, medium, and long term; and they developed specific implementation approaches.

These workshops are part of the ESD–OSI collaboration and are hosted by each NASA Center. In 2013, NASA plans to conduct a climate resilience workshop for NASA's coastal Centers and will initiate efforts for one focused on Washington, D.C., and the national capital region. NASA plans to hold a climate resiliency workshop for Marshall Space Flight Center in Alabama in 2014.



Stennis Space Center

NASA and the National Climate Assessment

Under the Global Change Research Act of 1990, the United States conducts periodic assessments of climate change, considering social, economic, and ecological implications. Each National Climate Assessment (NCA) evaluates climate impacts on U.S. regions and economic sectors and projects major trends for the subsequent 25 to 100 years. The third NCA, due for release in 2014, is the first to address cross-sectoral issues (such as urban infrastructure and rural communities) and sets up an ongoing assessment process. Climate vulnerabilities and adaptation strategies are documented through efforts to assess how communities and the nation as a whole can create environmentally sound and sustainable development paths.

NASA Earth Science has been a major contributor to the third NCA in terms of personnel, financial resources, scientific findings, and intellectual leadership. For instance, four NASA employees are serving as lead authors of NCA report chapters. ESD continued to detail

personnel to the NCA Coordination Office. ESD began in 2012 to support the development of climate visualizations to help communicate climate trends and NCA findings. Overall, involvement in the NCA has spanned ESD, including Applied Sciences, Research & Analysis, Flight Systems, Data Systems, and division leadership.



In addition, several climate assessment projects that ESD initiated in 2011 directly contributed to the third NCA. In 2012, some of the 14 projects from this solicitation delivered specific assessments of climate trends and impacts on sectors and regions to the NCA. Other projects developed tools to support ongoing climate assessment activities, such as data sets, scenarios, and visualization techniques.

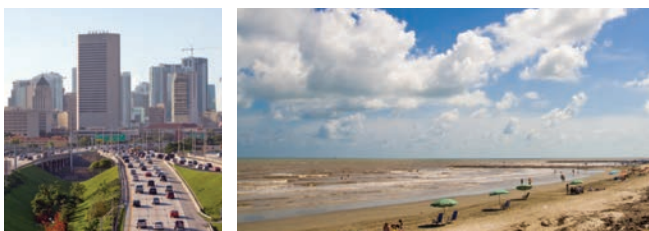
In response to the March 2012 public request for technical inputs, about 70 NASA program managers and scientists contributed directly to the third NCA activities. Countless NASA-supported Earth science investigators did as well, and many scientists have published results in scientific literature that informed the assessment.

NASA Goddard Institute for Space Studies, with Applied Sciences sponsorship, led the Northeast regional assessment. As part of its technical input, the team held workshops and listening sessions to gather information. For example, GISS held a listening session in Morgantown, West Virginia, in February 2012, providing a forum for resident input about climate and extreme weather-related issues at the local and regional scale. GISS held this session to supplement information on climate vulnerability assessment research around Central Appalachia. Following GISS's overview of the Northeast climatology and outlook of climate scenarios for temperature and precipitation change, the session turned to participant comments on risks, impacts, vulnerabilities of sectors and communities, and adaptations. The participants raised several topics that have not been captured in existing literature, such as the popular practice in the area of collecting wild ginseng.

Overall, they identified aquatic and terrestrial species as well as water resources as impacts. They discussed impacts of flooding on infrastructure, farming, sewage, and water treatment; they noted that the rural poor are

often those living in flood plains. Two main conclusions were the need for straightforward information materials and the role of local people to identify regionally specific impacts often outside the literature.

The release of the draft third NCA report for public comment is expected in early 2013. NASA ESD plans to support some NCA regional events to engage the public, encourage comments, and obtain input on the sustained assessment process. The final version of the report is expected in early 2014. To learn more, visit www.globalchange.gov/what-we-do/assessment/nca-overview.

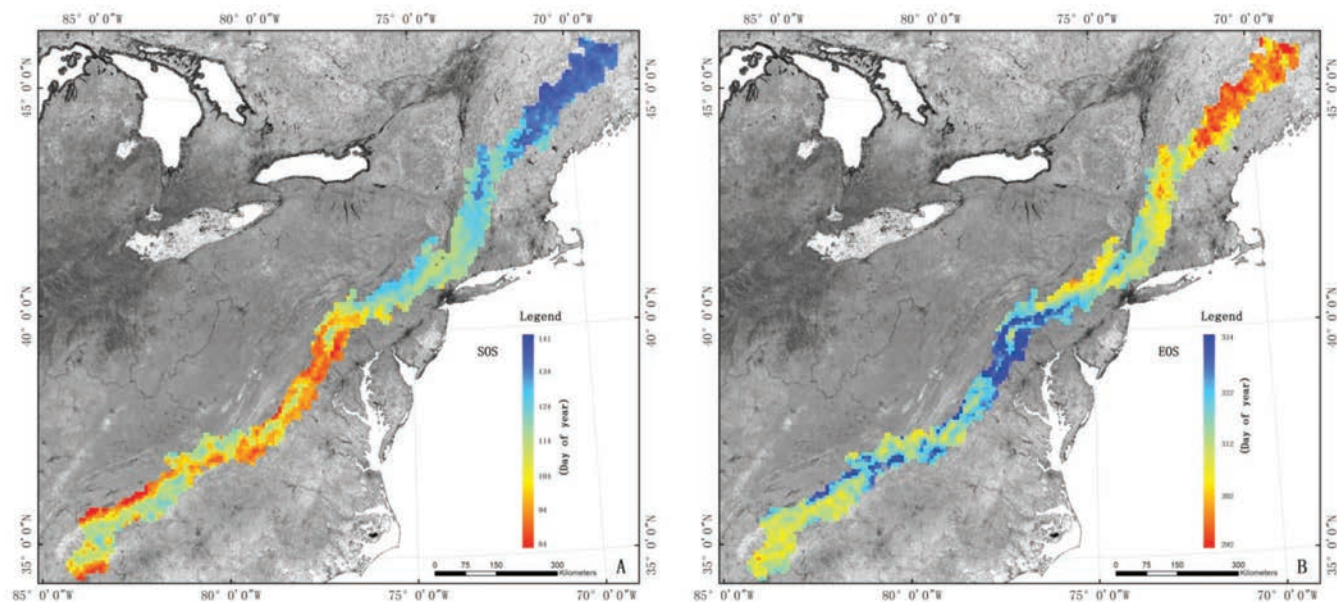


USGCRP Strategic Plan

The U.S. Global Change Research Program (USGCRP) coordinates and integrates federal research on changes

in the global environment and their implications for society. Thirteen departments and agencies participate in USGCRP. In 2012, USGCRP released a new strategic plan for the 2012–2021 period. The plan encompasses both fundamental research that improves understanding as well as research to inform responses to climate and global change. Four goals frame the strategic plan: advance science, inform decisions, conduct sustained assessments, and communicate and educate. The plan also emphasizes efforts to integrate research findings from the ecological, social, and economic sciences with physical sciences to understand changes in the climate and Earth system.

ESD has significant leadership roles in USGCRP and was very involved in the development of the new plan. Applied Sciences personnel were especially involved in the development of Goal 2, “Inform Decisions: Provide the scientific basis to inform and enable timely decisions on adaptation and mitigation.” This goal provides special attention to the delivery and application of research knowledge, tools, and climate data to support decisions across economic sectors and societal needs.



These figures illustrate trends in land surface phenology for the start of the season (SOS, left) and the end of the season (EOS, right) along a mega-transect area of the Appalachian Trail corridor from 1982 to 2006. Colors represent the day of year. For SOS, warm colors designate earlier in year; for EOS, warm colors designate later in year. Overall, the figures indicate an extended length of season, especially from a delayed end of season. NASA GISS, which addressed the Northeast in the National Climate Assessment, included these figures as part of its technical input to the NCA.



Applied Sciences Program Management

This section provides information on Applied Sciences' programmatic activities and performance in 2012, including work to estimate the socioeconomic benefits from the use of Earth observations in decision making.

This section describes significant efforts to increase the involvement of the applications community in early-stage planning activities for future Earth-observing satellite missions. This section also provides information on Applied Sciences' support to the intergovernmental Group on Earth Observations and a mobile app launched in 2012 called *Earth as Art*.



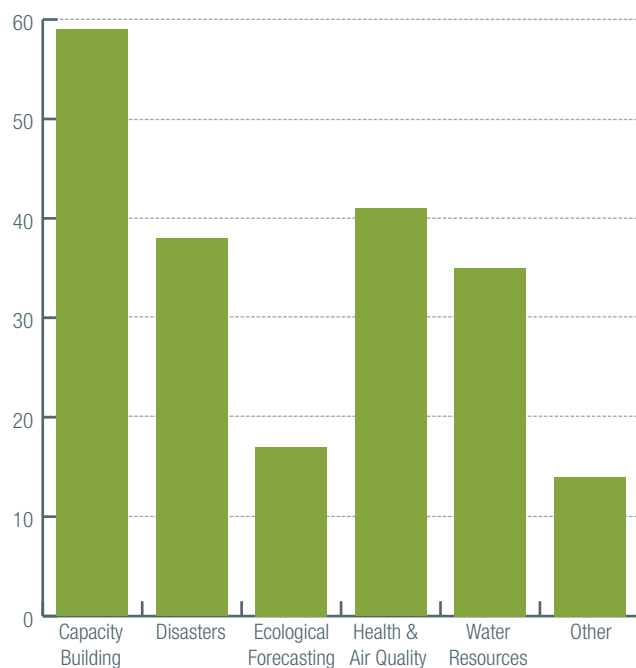
Program Goals, Project Portfolios, and Initiatives



In 2012, Applied Sciences pursued its goals, introduced new programmatic initiatives, and continued to implement major changes from previous years.

Program Goals and Portfolio

NASA's Applied Sciences Program discovers and demonstrates innovative uses and practical benefits of NASA Earth science and data from NASA's Earth-observing environmental satellites. By partnering with government agencies, businesses, and nonprofits to apply scientific findings and satellite data in their decision-making activities, the Applied Sciences Program delivers benefits of Earth science to society. All Program activities support goals to deliver near-term uses of Earth observations, build capabilities to apply Earth science data, and contribute to satellite mission planning to increase their utility. By working with partners—and continuing to build new collaborations—the Program identifies ideas and priorities for new applications.



Applied Sciences Program portfolio (number of projects).

Program Structure

As in previous years, the Program has two lines of business: applications areas and capacity building, which are described in depth in the second section of this report. The Program has four primary applications areas: Disasters, Ecological Forecasting, Health & Air Quality, and Water Resources. The Capacity Building program element includes four components supporting national and international activities to broaden the array of users applying Earth science data and knowledge. The Program conducts limited, ad hoc activities in five additional applications themes (Agriculture, Climate, Weather, Oceans, and Energy); the Program hopes to pursue them as full-fledged applications areas when financial and personnel resources allow. The Program's efforts to engage the applications community in the design of and planning for future satellite missions is an activity involving everyone in Applied Sciences.



The Applied Sciences Program's fiscal year 2012 budget was \$36.4 million. The Program primarily funds peer-reviewed, competitively selected projects that range from short-term, proof-of-concept studies to applied research to multi-year projects focused on putting applications into operational use.

In 2012, Applied Sciences selected projects in the Disasters and Water Resources Applications areas, a cross-cutting Wildfires area, and a SERVIR Applied Sciences team. In all, the Program granted 58 project awards in 2012: 11 applications-style SERVIR projects and 47 feasibility studies.



New Role: Associate

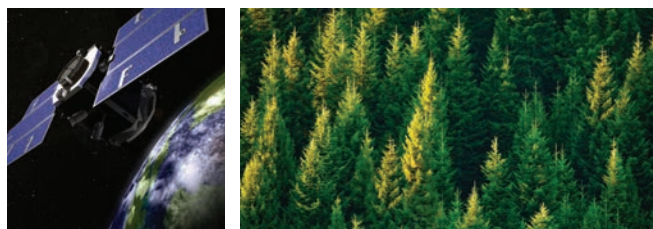
Applied Sciences added a new role of associate program manager in 2012 for each applications area. Based at NASA Centers, the associates track a set of projects, aiding their respective applications area program manager in maintaining more routine contact with the project teams and project partners. They help ensure the projects meet schedule, financial, and performance targets. The associates also support the program managers in engaging their respective applications end user communities and identifying investment opportunities and possible topics for solicitations. Overall, they encourage successful completion of projects and highlight accomplishments. Eight people began as associates in 2012, and the Program expects to add two more in 2013 for a total of 10.

Program Reviews

Applied Sciences introduced routine program reviews in 2012. Held every other month, the reviews provide a forum for each program manager to present the status of his or her respective program element. The managers discuss any studies or workshops, key challenges, changes to their project portfolio, and significant accomplishments.

For the applications areas, the respective associates provide either a brief summary or an in-depth discussion of four to five projects, including schedule, milestones, financial status, risks, progress, and achievements. These reports serve as an independent assessment of each project's status and prognosis, aiding Applied Sciences to understand where interventions are needed or where positive recognition is appropriate. For Capacity Building, the program manager reports on the program element overall, and usually two of the four components report in detail about their activities, finances, progress, and achievements.

At the program reviews, the Program staff examine Applied Sciences' overall financial status and progress toward the annual performance goals. The Applied Sciences director conveys information from NASA, SMD, or ESD leadership on key priorities, messages, or strategic initiatives.



Twice a year, Applied Sciences also holds a program review focused on the connections of applications and satellite mission planning. ESD identified program applications leads (PAs) in 2011 for each Earth science satellite mission in pre-formulation and development; the PAs are the applications equivalent of the program executive and program scientist for each satellite mission. Overall, the PAs help their mission teams identify design choices that would increase or diminish the applications value of the missions. In 2012, Applied Sciences began these applications-mission program reviews for the PAs to report on their respective satellite missions, especially progress in engaging the applications community in the missions and efforts to support mission development.

Initiatives and Studies

In 2012, Applied Sciences began the implementation of a redesigned database for the Program's projects. In addition to providing a consolidated and searchable archive of Program-wide information and achievements, the database is also a portfolio management tool. It streamlines project reporting and enables and encourages project teams to communicate additional information about their projects. This information is accessible to the entire program staff, thereby enhancing communications, capacity building efforts, program planning, and portfolio analysis. Completion of Phase 1 is expected early in 2013, at which point existing data will be migrated into the redesigned architecture and user interface, and project teams and Program staff will be registered and notified. This redesign phase includes the addition of customized project reporting tools, such as a new ARL assessment and tracking tool, new project data categories, and additional user permissions including a new role for the associate program managers.

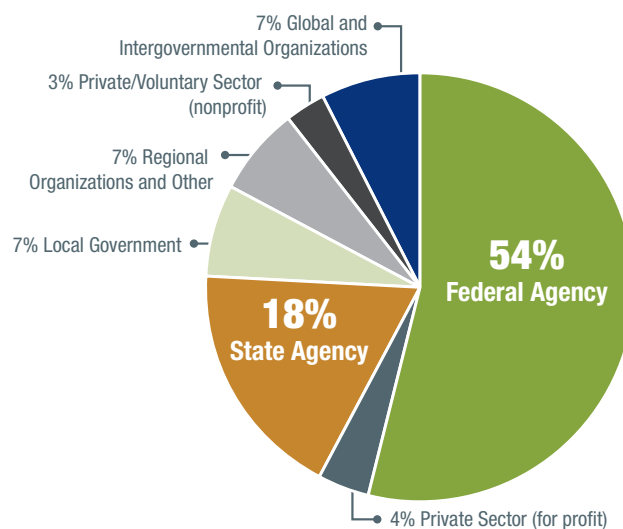
Applied Sciences began a study in 2012 to examine other nations' applied sciences programs. This study will benchmark the Program's strategy, implementation

methods, and performance measures against those of other countries and international organizations. After a broad survey of programs in the first phase, the study includes in-depth analysis and case studies in the second and third phases. Completion of this study is expected in mid-2013. Overall, this study will aid the Program in examining its methods and considering additional ways to facilitate and promote the use of Earth observations for societal benefit.

The Program also initiated studies on the scientific and technology "heritage, pedigree, and lineage" of two applications projects. The studies examine the pathways that led from the sensors, satellites, algorithms, data access, and research to practical applications that support specific decision-making activities. The studies will aid in understanding effective approaches to translate research and development into applications and sustained uses. The studies will complete in 2013, when the Program will consider broadening the initiative. Applied Sciences sponsored a special session on this applications "heritage" topic at the AGU Fall Meeting in December 2012.

Additional Activities

The following section discusses additional activities that Applied Sciences conducted in 2012 related to management of the Program and support of the applications community. For example, it discusses the Program's annual performance goals, impact analyses, and activities to quantify the socioeconomic benefits derived from applications of Earth observations. It also describes the Program's efforts to increase applications engagement with planning for upcoming satellite missions.



Types of end user organizations in applications projects with the Program.

Applications Area Associates

In 2012, the Applied Sciences Program introduced an associate program manager (associate) role for each applications area. An associate monitors projects in a respective applications area, overseeing progress to apply NASA Earth science products in decision making. Each associate manages a portfolio of projects to encourage and ensure they meet schedule, cost, and performance objectives.

The associate works with the applications area program manager in identifying opportunities, engaging users, and assessing risks to successful project completion. The associate also develops new partnerships and appraises the program manager of important issues. Mostly, the associate nurtures projects and draws attention to their outcomes and achievements.

In February, the new associates met at a kickoff meeting at NASA Headquarters to discuss their

roles and responsibilities and meet directly with their respective applications program manager.

The associates have expertise in Earth science and remote sensing, as well as knowledge of applied research, applications, and other relevant topics. The associates are:

- **Disasters:** John Murray
- **Ecological Forecasting:** Maury Estes, Gary Geller, and Jay Skiles
- **Health & Air Quality:** Sue Estes and Ali Omar
- **Water Resources:** Forrest Melton and Karen Mohr

The associates enhance how Applied Sciences manages projects, identify investment opportunities, and highlight results and accomplishments. In 2013, the Program expects to add two more associates: one for Disasters (with a geohazards focus) and one for Wildfires.



Anti-Atlas Mountains, Morocco.

Earth as Art

Achieving Program Goals



In 2012, the Applied Sciences Program achieved its annual performance goal. Scores of projects advanced in their application readiness.

Annual Performance Goal

The Applied Sciences Program achieved its 2012 annual performance goal for at least 25 percent of its decision support projects to advance at least one Application Readiness Level (ARL). Of the 124 projects assessed at the end of FY 2011, 108 were still active during FY 2012. Sixty-six of those projects (61 percent) had advanced one or more ARL by the end of FY 2012.

FY 2012 was the first year Applied Sciences used the new ARL-based performance metric in its annual performance goal. The Program gathered ARLs at the end of FY 2011 and at the end of FY 2012 on decision support projects active during each respective year across the applications areas and the Capacity Building program.

Enhancing Water Supply Management

The New York City Department of Environmental Protection (NYCDEP) uses a watershed hydrology model in decision making about the city's water supply. An Applied Sciences project is studying the feasibility of applying remote sensing data to assess and calibrate the hydrology model, with an emphasis on low-flow (dry summer) conditions.

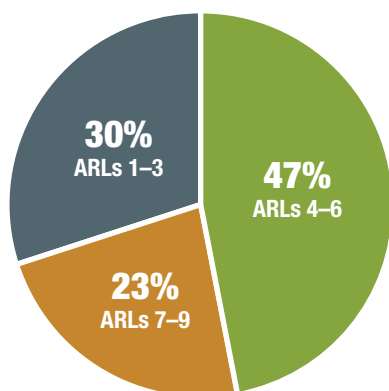
The project began in mid-2012 at ARL 1. During the year

the project team compared MODIS evapotranspiration and other data products with output from the existing model. It also classified the data products for their suitability in assessing watershed hydrology. The project ended the year at ARL 2. In 2013, the team will perform model calibration and compare the calibrated model with the baseline model. The team will also prepare plans for full-scale use of selected remote sensing products to improve NYCDEP decision making, concluding the project at midyear at ARL 3.

Portfolio Performance

In FY 2012, 40 decision support projects (38 percent of the total) advanced more than one ARL, and the Program's portfolio of projects spanned the entire range of the scale, including five projects that reached ARL 9.

Overall, 23 percent of the Program's decision support projects that had either concluded or were still under way at the end of FY 2012 were deploying into the partner organizations' decision support environments (ARLs 7–9), 47 percent were developing and validating their applications concepts (ARLs 4–6), and 30 percent were assessing their feasibility in the proof-of-concept stage (ARLs 1–3). The pie chart illustrates this categorization of projects.



Program portfolio progress towards improved decision making.

Improving Decisions on Public Health

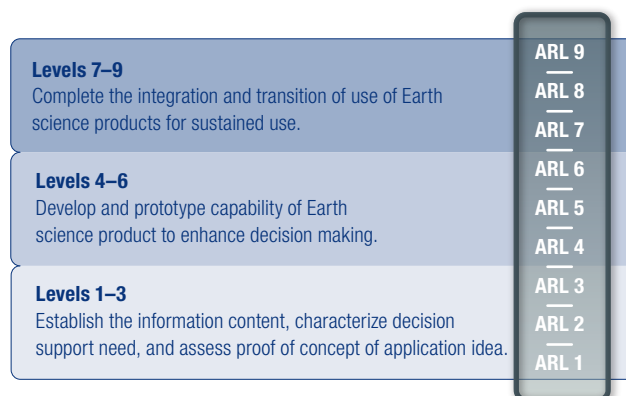
In the public health field, specialists and officials use the online CDC WONDER system to obtain a variety of data to support decisions on public health issues. The system provides access to a range of public health information, particularly for state and local health agencies. A Program-funded project aims to bolster CDC WONDER with certain environmental data sets, enabling disease specialists and decision makers to better assess risk and protect public health (see pages 32–33).

The project began in 2009 at ARL 4. In 2011, the project team developed a “mirror” Web page to allow limited access to the land surface temperature data. The page resembled in both design and function what the live page

would eventually be; this allowed the project to reach ARL 5. In 2012, the team integrated solar insolation and PM2.5 data into CDC WONDER, and the new data sets went live, resulting in ARL 8. After the team makes additional adjustments based on end user feedback, the data sets will be easier to use. The team expects to complete the project at ARL 9.

Future Performance Goals

The Program’s 2013 and 2014 annual performance goal calls for at least 25 percent of the decision support projects to advance at least one ARL. The Program will assess the annual performance goal after three years and adjust percentages as appropriate.



Depiction of the Application Readiness Levels.

Application Readiness Levels

In 2011, the Program introduced and refined a nine-stage ARL metric to track the maturity of applications projects—from the initial idea, through its stages of development, to its transition to operational use. The Program assesses the projects’ ARLs on a routine basis throughout the year. On the ARL scale, ARL 1 represents basic research and ARL 9 represents operational deployment and use in decision making. ARLs 1–3 generally focus on discovery, feasibility, and proof of concept. ARLs 4–6 focus on application

development, testing, and validation. And, ARLs 7–9 focus on application demonstration and transition into operations.

The ARL index provides a scale for Applied Sciences program managers to convey the expected advancement of applications projects and to assess the actual progress of a project. Project teams can use the ARL scale to establish and articulate key project milestones.

Building Capabilities to Quantify Benefits of Earth Observations



Applied Sciences expanded its efforts to build capabilities in substantiating the socioeconomic benefits from applications of Earth observations.

Applied Sciences has initiated and supported activities in recent years to quantify socioeconomic benefits from the use of Earth observations. The activities seek to bridge a gap among the Earth science, social science, economics, and policy analysis communities and identify an applied research agenda to advance analytic methodologies. In 2012, the Program pursued numerous efforts on this topic, including impact analyses (see page 79), a workshop, conference sessions, and a forthcoming primer.

Building Awareness and Advancing Techniques

In June, the Program sponsored a Workshop on Defining, Measuring, and Communicating the Socioeconomic Benefits of Earth Observations. This event was the third in a series of annual workshops, and it included a pre-event tutorial. Primarily, it reviewed quantitative methodologies for assessing and communicating the value of geospatial information.

The workshop had keynote talks, topic presentations, case study examples, and breakout sessions. Overall, it covered a range of analytic techniques and a variety of applications. For example, one talk addressed use of benefit-cost analysis on water resources, one explained a contingent valuation method for *Landsat* data, and one discussed an ROI methodology applied to flood response.

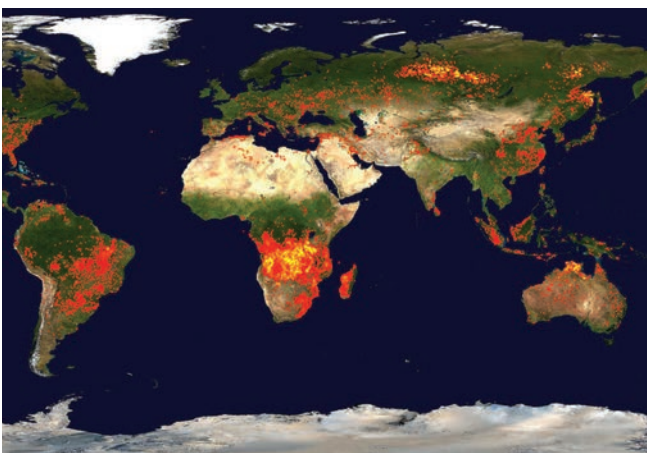
In addition to methodologies, the workshop examined issues around the communication of quantitative benefits to target audiences. In a keynote talk, OMB's Dan Rosenbaum discussed framing issues from a decision maker's perspective. He noted that decision makers are often inundated with studies using different and sometimes complex methods, with little time to fully evaluate issues and all of the evidence. One suggestion was to develop a set of standards for geospatial information analyses so that studies that are endorsed meet those requirements.



Breakout sessions pursued specific topics in depth. A set on one day focused on the types of quantitative methodologies, components of desirable case studies, and effective communication approaches. On the final day, some attendees identified pros and cons of the alternative methodologies while others discussed case studies to apply the methods.

One key conclusion was the need and call for more case studies, which should cover a wide range of topics and methods of analysis. Attendees also identified that communication to decision makers requires either succinct quantitative statements of value based on rigorous models or user testimonials of actual applications with concrete benefits.

This 2012 event included a half-day tutorial prior to the workshop, offering attendees an introduction to key concepts and methodologies on economic methods as well as Earth science data and remote sensing techniques. The tutorial had three parts. The first provided the conceptual basis for the analysis of societal benefits and meanings of “value” and “benefit.” The talk addressed that a framework to match the collection (supply) of Earth observations and the use (demand) must be able to evaluate what attributes of the information are most useful. Part two described Earth-observing satellites and their data, and it provided examples of how the data could be used in decision and policy making. Part three focused on the concept and application of cost-benefit analysis to assess the value of geospatial information, using a specific case study as an example. Molly Macauley (Resources for the Future, RFF), Molly Brown (NASA), and Richard Bernknopf (University of New Mexico) organized and ran the tutorial.



Applied Sciences has conducted these annual workshops in collaboration with the European Commission's Joint Research Center (JRC). The IEEE Committee on Earth Observation organized the 2012

workshop, and NCAR and Natural Resources Canada's GeoConnections program provided support.

Conducting Impact Analyses

Applied Sciences continued to support the production of project-specific analyses of the socioeconomic benefits associated with the use of Earth observations. The Program completed two studies in 2012. One focused on use of satellite data for wildfires and air quality planning, and one focused on use of Earth observations to support fisheries management. Pages 81–82 describe these impact analyses.



Leading Community Events

Together with IEEE, RFF, and the University of New Mexico, the Program organized an “Assessing Socioeconomic Benefits of Earth Observation Science” session at the 2012 AGU Fall Meeting. More than 20,000 people from the Earth science community attended the meeting, and the session provided a chance to introduce this community to economic analysis.

The session presented a range of analytic techniques and tools. It included presentations on assessing the economic value of climate science, quantitative performance measurement frameworks, and value of information of climate change indicators. The related poster session included topics on Earth observations and wind-energy prospecting, hidden costs of exposure to landscape fires, and the value of *Landsat* imagery.

In 2012 Applied Sciences also supported the IEEE Global Humanitarian Technology Conference, which addressed the use of technologies to improve human livelihood. The Program participated in a special panel on societal impacts and benefits, which discussed the socioeconomic benefits of Earth observations. One speaker addressed the value of Earth observations for monitoring agricultural land-use activities and

the geographically variable impacts of nitrates on groundwater quality. Another spoke on public health benefits from improved public access to water quality notices enabled by geospatial technology. Applied Sciences' Nancy Searby discussed the SERVIR venture and development of indicators to support impact assessments of Earth observations in developing countries.

Looking Ahead

As the year ended, Applied Sciences completed work on a primer, *Measuring Socioeconomic Impacts of Earth Observations*. The primary audience is the Earth science community, and the main purpose is to introduce key terms, principles, and methodologies from economic analysis. This primer includes two case studies for illustration. The Program will publish the primer early in 2013, and the Applied Sciences website will have a digital version.

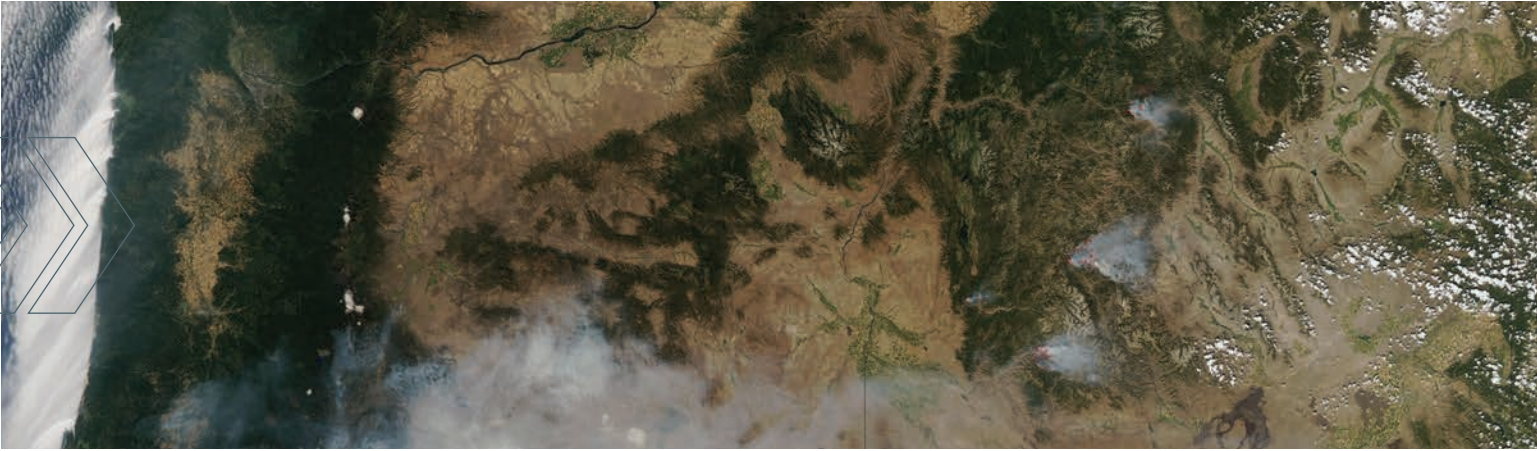
The Program will also complete new impact analyses. For the annual workshop on benefits of Earth observations and geospatial information, JRC will host the event in Europe and a key theme will be innovation. In addition, the theme of the 2013 Geospatial World Forum is "monetizing geospatial value and practices." The Program supported efforts to organize a seminar on societal impacts and benefits of improved environmental and geospatial information. The day-long seminar will share experiences in using proven economic and financial methodologies; it will have tutorials on techniques, showcase major projects, and present best practices for valuing geospatial applications.



Bombetoka Bay, Madagascar.

Earth as Art

Measuring the Value of Earth Observations



Applied Sciences completed analyses of the socioeconomic impacts of the use of Earth observations in 2012. These independent impact reports complement ones from prior years and underscore Applied Sciences' emphasis on quantifying the benefits of Earth observations.

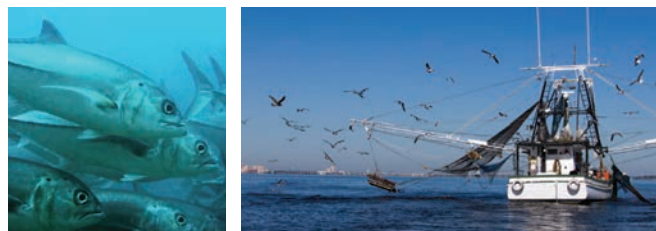
Improving Fisheries Management

Managing fisheries in sustainable ways supports commercial and recreational fishing interests. The decline or loss of fisheries can have significant economic impacts and can threaten the survival of species. Reliable data and information on fish reproduction and growth to adulthood inform managers' estimates of fish populations. Information about fisheries stocks and habitats enable fishery managers to identify species at risk and consider measures such as quotas or closure of fishing areas.

Applied Sciences has funded projects that focused on applying Earth observations to inform and improve fisheries management. For example, one project created a custom software module to analyze habitats of commercially exploited or threatened species (see pages 41–42). A second project developed a technique to assess the population of the Atlantic bluefin tuna. These projects incorporated observations of ocean chlorophyll concentration, sea surface temperature, and sea surface height from satellites such as *Aqua*, *Jason*, and *Terra*.

The analysis of these projects examined the relative value that Earth observations contributed to accurate stock

size assessments, through improvements in targeting larvae sampling sites and through improvements in calculating population size. To quantify the relative value of improved stock size estimates, the impact analysis team first estimated the market value of the relevant fisheries with catch data.



Using these data and a discount rate of 5 percent a year, on a moving average of sales volume, the team calculated the present discounted value of various species and then the first-order economic costs of a collapse or shutdown of fisheries. In other words, the team determined the discount rate (a calculation of the reduction in value associated with the passage of time) using a moving average (a series of averages of subsets of the full data set) of sales volume. Additionally, the team calculated the benefits of improved estimates that reduce

the uncertainty of stock size and thus reduce the risk of fishery collapse.

The team estimated that the Applied Sciences projects reduced by 17 percent the probability of collapse of Atlantic bluefin tuna fisheries over the next decade. The team's analysis generated net present values of risk mitigation for the two projects: \$21 million for Atlantic bluefin, \$3 million for Pacific bluefin, and about \$300,000 for yellowfin tuna. In other words, the Earth observations helped improve the accuracy of stock size assessments; those are the estimated values of the improved knowledge in current dollars. The estimates are potential rather than realized gains. Fishery managers can achieve a potentially beneficial effect by using NASA data to reduce the uncertainty of stock size, thereby substantially reducing the risk of fishery collapse.

Enhancing Air Quality Predictions

Every year, wildland fires cause hundreds of millions of dollars in property damage in the United States. While prescribed (controlled) burning to reduce excess vegetation can decrease wildfire risk, such burning can also negatively affect human health and economic activity in ways similar to the wildfires they are meant to prevent. Land and fire management professionals thus need tools that can predict the extent and density of smoke plumes that might result from a prescribed burn. Public health authorities also need to predict the impact of uncontrolled wildfires, so that they can issue appropriate and timely air quality warnings.



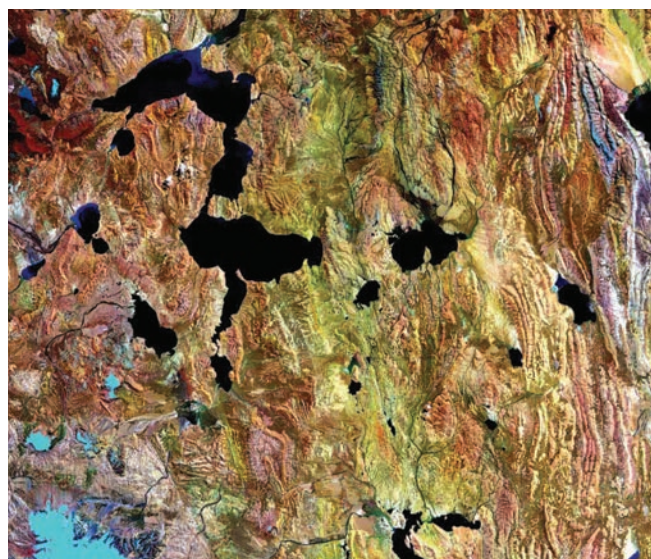
Applied Sciences sponsored a project to extend NASA Earth science to BlueSky, a USFS modeling framework to predict the cumulative effects of smoke from forest, range, and agricultural fires. The project integrated MODIS and other remote sensing data products to improve the accuracy and timeliness of BlueSky as well as improve predictions of emissions and air quality effects from fires.

The impact analysis of the BlueSky project focused on the upstream impact (amount of burning) related to prescribed burning decisions, and a downstream impact (improved health) with respect to health warning decisions. The analysis team focused on California,



due to the availability of data and advice of members of the user community. California land, fire, and air quality managers had access to BlueSky smoke forecasts beginning in 2004, and they used the enhanced BlueSky tool from 2006 onward. The team calculated the means and standard deviations for the number of prescribed fires per year, acres burned per year, and mean acres burned per year. The analysis team also estimated health impacts by comparing cardiopulmonary hospitalizations during major wildfire periods before and after the addition of NASA data to BlueSky.

The team estimated that the BlueSky project resulted in 4 percent to 5 percent more prescribed burns annually. In addition, the team's analysis of the impact of improved BlueSky forecasts on cardiopulmonary hospitalizations during major wildfire periods suggested that the number of hospitalizations and the associated costs could be substantially lower when improved forecasts are available and health officials use them. For example, the team estimated the impact on Sacramento County during the 2008 wildfire season was a potential reduction of 147 cases and \$195,000 in costs for each two-week period.



Tibetan Plateau, Central Asia.

Earth as Art

Supporting Applications in Satellite Mission Planning



In 2012, Applied Sciences enabled the applications community to engage in the design and mission planning for Earth-observing satellites.

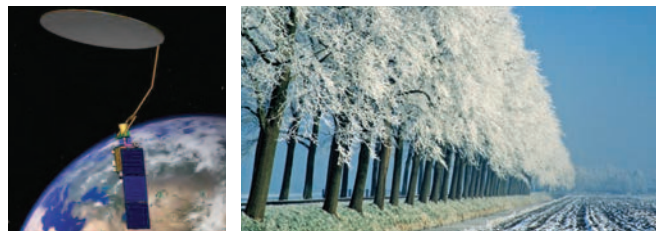
For new and upcoming Earth-observing satellites, NASA ESD encourages organizations to become involved in satellite mission planning throughout the mission life cycle. In early stages, they can support mission design, inform trade-off decisions, and identify ways to enhance the applications value of the satellites. In later stages, they can provide feedback on the design of data products, anticipate potential applications, and be prepared to use the data soon after launch.

In 2012, Applied Sciences continued to engage organizations and satellite mission teams to examine and integrate applications in the design and development of the Earth science satellites. Several missions conducted applications workshops, and some events addressed applications that combine data across missions. The Program launched a study on data latency issues and will support mission-specific applications studies beginning in 2013.

SMAP Applications and Early Adopters

The upcoming *Soil Moisture Active Passive (SMAP)* satellite mission will map global soil moisture and its freeze/thaw state from space. These measurements support analyses on trends in water availability and whether there will be more or less water regionally compared with today. The data can support improved flood prediction, drought monitoring, weather forecasting,

wildfire risk assessment, and food security. Overall, the *SMAP* mission has both high science and applications value. Susan Moran, USDA, leads the *SMAP* Applications Working Group.



In 2012, *SMAP* initiated activities to focus on specific applications communities, allowing the mission to pursue in-depth discussions with users on key topics and applications themes. *SMAP* held a meeting in February with the urban modeling community at Arizona State University. Focused on how *SMAP* soil moisture data can be used at city scales to address urban water management modeling, the attendees addressed issues related to the format of the data and its delivery mechanisms to quickly use *SMAP* data after its planned 2014 launch. Among the conclusions to support integration of *SMAP* pre-launch test data, the attendees suggested that data formats be in netCDF and other GIS-friendly formats, and they requested access to algorithm reports.

SMAP: New Early Adopters in 2012

SMAP created an innovative Early Adopters program for organizations that have clearly defined uses for SMAP-like data products. Early Adopters receive simulated SMAP data products to evaluate and demonstrate the utility of SMAP for their particular decision-making activities. Using their own resources, Early Adopters provide feedback on data products to increase SMAP's application value and streamline uses of SMAP data soon after launch. SMAP selected seven organizations in 2011 as the inaugural Early Adopters. Eleven entities (nine organizations and two groups of organizations) became Early Adopters in 2012.

To learn more, visit <https://smap.jpl.nasa.gov/science/wgroups/applicWG/EarlyAdopters>.



SMAP also organized a focus session at the Palo Verde Nuclear Generating Station in Arizona. During an emergency response exercise at this station, SMAP representatives participated to demonstrate the value of satellite data for emergency planning, explaining how soil moisture data could be used for scenarios in which nuclear fallout has occurred. Representatives from StormCenter Communications, an Applied Sciences Program grant recipient, also participated to demonstrate a real-time data integration and visualization tool to support collaboration for the station's geospatial common

operating picture. Among the results of the focus session, operators identified their need for data sets displaying soil moisture and air moisture within 20 miles of the plant.

SMAP had created an Early Adopters program in 2011 for organizations that have clearly defined uses for SMAP-like data products. In 2012, SMAP selected 11 organizations from business, academia, and state and federal government to join its Early Adopters program. See the callout to the left.

To learn more about SMAP and its applications working group, visit <https://smap.jpl.nasa.gov>.

ICESat-2 Applications

The Ice, Cloud, and Land Elevation Satellite-2 (ICESat-2) mission will measure ice sheet mass balance, cloud and aerosol heights, and land topography and vegetation characteristics. Providing multi-year elevation data, the orbiting laser altimeter will support assessments of polar ice changes and vegetation canopy heights, allowing estimates of biomass.



ICESat-2 was very active in 2012 engaging the applications community in the mission. In April, the mission

held its first applications workshop, resulting in an information exchange with more than 30 organizations. The talks introduced potential users to the ICESat-2 mission, including information on potential ice sheet, sea ice, land elevation and vegetation, coastal water elevation, inland water height, and atmospheric applications of ICESat-2 data. Thematic breakout groups allowed users and product developers to interact, including discussions on needs for near real-time data products for certain communities. For example, the National Ice Center and the U.S. Coast Guard identified potential applications and their interests in near real-time products for sea ice.

The ICESat-2 mission will use a photon-counting approach to detect ground elevation and canopy height in heavily forested environments (the difference of these gives the forest canopy). Some workshop participants, especially those focused on vegetation applications, expressed a need to examine pre-mission, airborne simulator data to better understand the approach and thus potential applications.

As introduced at the workshop, ICESat-2 plans to pursue an early adopters program for organizations with mature applications and clearly defined uses for ICESat-2-like

data products. The mission expects to announce a call for early adopters in late 2013. In 2012, NASA ESD selected the National Snow and Ice Data Center (NSIDC) to serve as the data distribution facility for the mission, and the *ICESat-2* team began work with NSIDC on approaches for applications and user engagement.



In 2012, *ICESat-2* developed an applications plan that outlines activities to engage the applications community both before and after launch, which is planned for 2016. The mission plans to have applications workshops annually during the pre-launch phase, with additional focus sessions during the year. The mission expects to post the *ICESat-2* Applications Plan to its website in early 2013.

To learn more about *ICESat-2*, visit <http://icesat.gsfc.nasa.gov/icesat2>.

SMAP/ICESat-2 Applications Tutorial

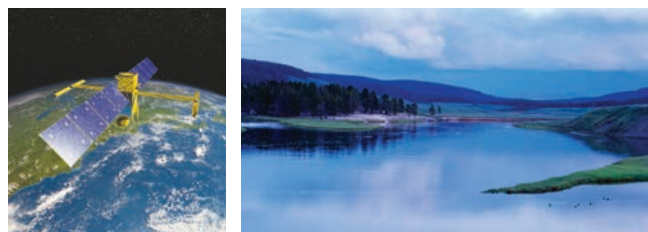
Applied Sciences encourages the combination of data products across Earth science satellite missions to support applications and enhance decision making. In 2012, this effort extended into future satellite missions.

The *SMAP* and *ICESat-2* missions organized a joint applications tutorial in 2012, which examined combined uses of *SMAP* freeze/thaw and soil moisture data and *ICESat-2* altimetry data. Hosted by the Alaska Satellite Facility, the event supported Alaskan applications communities to identify opportunities and express needs, especially on northern forests, cryosphere, and land and ocean applications. The tutorial encouraged innovative applications in both hydrosphere and cryosphere using products from existing missions and possibilities of using future mission products together. Among the outcomes, the attendees expressed a strong interest in joint-mission sea ice and permafrost products. For example, a geomorphology permafrost product for the U.S. Department of Transportation and the U.S. Bureau of Land Management could support assessments of permafrost melt in thermokarst areas and the resulting slumping of the land surface. Mission representatives held subsequent meetings in 2012 with ASF, DoD, and NRL to help guide the development of products identified at the tutorial; additional meetings are planned for 2013 and beyond.

Four-Mission, Hydrology Applications Tutorial

Four future, water-related satellites—*SMAP*, *GPM*, *GRACE-FO*, and *SWOT*—supported a joint mission workshop in 2012 to explore how the combination of data products can help in hydrological applications and challenges at global and local scales. Hosted by USGS, the event focused on collaborative opportunities among these missions (and existing ones) to ensure the usefulness of water-related satellite missions to the broader user community. Each satellite mission sent at least four scientists or team members to engage with the participants, who led or worked for national hydrological programs.

Breakout sessions focused on four applications topics: drought, flooding, water management, and weather and extreme events, and identified data challenges (such as latency and format) and potential user organizations. Among the conclusions, the attendees identified a multi-mission drought product to monitor drought in unprecedented detail, supporting new levels of diagnosis about meteorological drought (deficit in precipitation), agricultural drought (deficit in soil moisture) and hydrological drought (deficit in groundwater and stream-flow).



At the event, Eni Njoku, the *SMAP* mission scientist, announced that *SMAP* calibration and validation data would be made available to all qualified applicants, supporting pre-launch applications preparations and uses of soil moisture data in different modeling systems.

Suomi NPP Workshop

The *Suomi NPP* satellite is an interagency mission with a suite of five sensors to collect measurements of sea and land surface temperatures, clouds, vegetation, ocean color, ice cover, ozone and aerosols, solar incidence, and many other environmental parameters. The mission continues key measurements from the *Terra*, *Aqua*, and *Aura* research satellites, serving as a bridge between these satellites and the next generation of operational, polar-orbiting satellites. Thus, the *Suomi NPP* mission extends applications discovered and made possible from previous satellites and will enable new applications.

Given the significant applications value of the mission,



Applied Sciences held a *Suomi NPP* applications workshop in 2012 in cooperation with NOAA, USDA, and USGS. The workshop informed users about the *Suomi NPP* instruments, data products, and access to data. Speakers updated the applications community on instrument performance and data characteristics, and breakout sessions allowed attendees to discuss specific applications and provide feedback on data products and access.

Participants noted that many applications rely on derived indicators that relate current conditions to various statistical summaries of long-term historic ranges. Thus, they strongly recommended re-processing of the full *Suomi NPP* data record (or for individual sensors) following changes in data processing algorithms.

To learn more, visit
http://geo.arc.nasa.gov/npp/npp_conf_index.html.

***HyspIRI* Symposium and Science Workshop**

The *Hyperspectral Infrared Imager (HyspIRI)* satellite mission will measure vegetation health, study the world's ecosystems, and provide critical information on natural disasters, such as volcanoes and wildfires. *HyspIRI* held a symposium in May focused on higher level data products that might arise from the mission with a particular focus on disturbances and human impacts; ecosystem function and composition; and volcanoes, natural hazards, and mineral resources. These topics allowed consideration of products relevant to a host of applications.

In October, the three-day *HyspIRI* Science Workshop examined preparatory science activities, key technologies, mission partnership opportunities, and potential applications. The second day was almost entirely devoted to applications with presentations on agriculture, fires, volcanoes, coastal ecosystems, floods, mineral identification, and water quality. Attendees expressed interest in a 2013 *HyspIRI* airborne campaign and the data it will provide for applications research.

In a pre-formulation phase, *HyspIRI* is conducting studies

to inform the overall mission design, including ones to augment the applications value. In 2013, Applied Sciences expects to support one or more mission design studies, such as one examining the optimum revisit interval and time-of-day measurements for mapping evapotranspiration, which is key to managing water resources.

To learn more about *HyspIRI* and the events, visit
<http://hyspiri.jpl.nasa.gov>.

Earth Venture

In recent years, ESD initiated a new class of missions known as Earth Venture (EV). These EV missions provide an innovative, rapid, cost-constrained approach to advance Earth system science with periodic opportunities for satellites, instruments, and suborbital projects.

In 2012, ESD announced two EV selections: one for a full satellite mission and one for an instrument to fly on a mission of opportunity. Each of the selections has a significant applications dimension.



In June, ESD selected the Cyclone Global Navigation Satellite System (CYGNSS) mission. Using a constellation of eight micro-satellites, CYGNSS will measure ocean surface winds throughout the life cycle of tropical storms and hurricanes. For the first time, scientists will be able to probe key air-sea processes that take place near the inner core of the storms. The new knowledge and data can help lead to better weather forecasting and provide information to support hurricane forecasts.

In November, ESD selected the Tropospheric Emissions: Monitoring of Pollution (TEMPO) project, which will build the first space-based instrument to monitor major air pollutants across North America hourly during daytime. The instrument will likely be hosted by a commercial satellite in geostationary orbit. From this vantage point, TEMPO will measure diurnal variations in concentrations of air pollutants. Such measurements can support and improve air quality forecasts.

Latency Study

The time-criticality of data delivery of satellite measurements (aka data latency) is a major factor in the



utility of data products for applied and operational uses. Many of the future satellites missions have data products that could be extremely valuable if they reach the applications communities quickly after collection, yet some applications do not require such time-criticality to serve the decisions.

ESD, led by Applied Sciences, initiated a study in 2012 to assess options for meeting latency needs of the satellites. One aspect of the study will examine latency desires of the applications and scientific user communities for the data products. A second aspect will assess technical capabilities and available options to serve the specific needs. The study will support the planning process for each satellite, inform design trade-offs, and supports ways to improve access of data to more user communities.

Future Activities

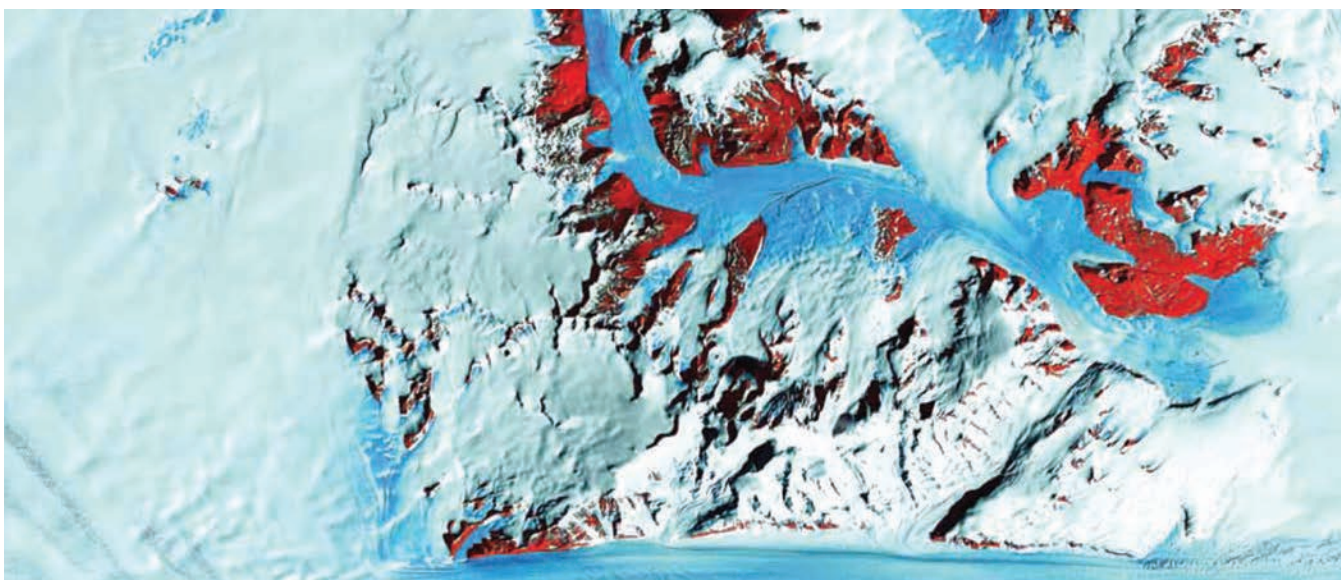
Building on this productive year, the Program will continue to engage applications communities in mission planning. Applied Sciences will host the first applications workshop for the *GPM* mission and one for the *OCO-2* mission. *SMAP* plans to select its third round of Early Adopters in 2013, hold a focus session on insurance

“[Applied Sciences] has begun to engage applied researchers and governmental operational users on some decadal survey mission science definition and applications teams and to conduct research to better understand the value of these applications.”

**National Research Council,
A Midterm Assessment of NASA's
Implementation of the Decadal Survey**

topics, and pursue specific user-driven data products on permafrost, military mobility, and wine production. *ICESat-2* expects to initiate its early adopters program, hold a focus session with military users, and release its applications plan. *GRACE* plans to launch an applications section on its website, and the *HyspIRI* symposium will have a special focus on the Program's applications themes.

In addition, the NASA-USGS *LDCM* satellite (aka *Landsat 8*) is scheduled to launch in February, continuing a 40-year record of global land cover with significant roles in applications. Visit the Applied Sciences website for information about applications-oriented meetings and events for satellite missions.



Byrd Glacier, Antarctica.

Earth as Art

Expanding Literature on Earth Science Applications

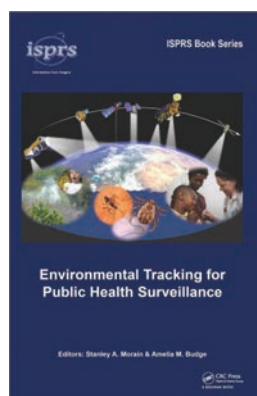


Project teams supported by Applied Sciences publish their results in a variety of technical journals and trade publications to reach scientists as well as managers, policy analysts, and business leaders. The past year was especially notable as two Program investigators published technical books—one on Earth science applications for public health, and one on the value of information.

Environmental Tracking for Public Health

Environmental conditions and hazards have substantial effects on public health. Identifying links between environmental conditions, exposure, and associated health effects can improve surveillance and enable quicker responses by government officials and health workers to environmental public health issues. Data and imagery from Earth-observing satellites are growing in use in public health, especially for surveillance to provide early warning of disease outbreaks.

Applied Sciences investigators Stanley Morain and Amelia Budge edited *Environmental Tracking for Public Health Surveillance*, which CRC Press published in 2012. The 480-page book describes the incorporation



of environmental tracking data from Earth-observing satellites and other sensors into geophysical and spatial information system models. These models enhance public health surveillance and decision making. Experts in both health and Earth science technologies jointly wrote the chapters. Topics include Earth observations for health applications; infectious and

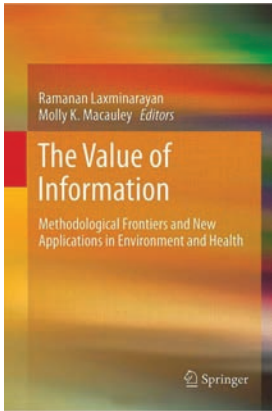
contagious diseases in the environment; air quality; data, modeling, and information systems; and early warning



To learn more about *Environmental Tracking for Public Health Surveillance*, visit www.crcnetbase.com/isbn/9780203093276.

systems. The publication is part of the ISPRS Book Series in Photogrammetry, Remote Sensing and Spatial Information Sciences.

Valuing Information and Earth Observations



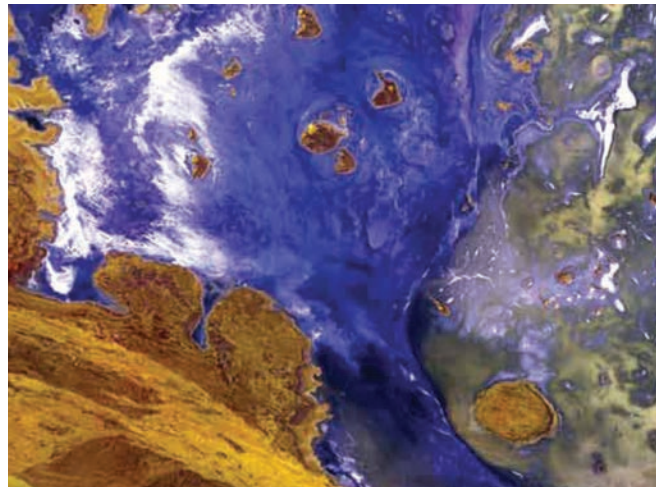
Resources for the Future (RFF) and the Applied Sciences Program conducted a workshop in 2010 to enhance efforts to quantify socioeconomic benefits from the use of Earth observations. Building on innovative methods in the health field, the workshop examined analytic techniques for calculating the value of Earth science information in decision making.

Commissioned papers and pre-arranged discussants addressed various methods used in ascribing value to information. Attendees were from government, academia, and the private sector, including leaders from environmental sciences, public health, physical sciences, economics, and social sciences.

RFF's Molly Macauley, an Applied Sciences investigator, and Ramanan Laxminarayan edited *The Value of Information: Methodological Frontiers and New Applications in Environment and Health*, which is based on the workshop. Published in 2012 by Springer, the 331-page book identifies five discrete approaches at the frontier of methodological advances: price- and cost-based derivation, Bayesian belief networks, regulatory cost-effectiveness evaluation, econometric modeling and estimation, and simulation modeling and estimation.

Program investigators continued to contribute publications on Earth science applications, including books in 2012 on health and socioeconomic impacts.

The book presents terms to describe what is meant by “value” and identify steps to ascribe, measure, and communicate value. Chapters include a variety of topics, such as understanding the value of business information, space imaging and prevention of infectious disease, consumer choice in health care markets, and a risk management approach to climate change. The collection posits that those who invest in information collection must better understand the needs of those who use the information.



Lake Disappointment, Australia.

Earth as Art

To learn more about *The Value of Information*, visit <http://link.springer.com/book/10.1007/978-94-007-4839-2/page/1>.



Examining Connections in Science and Climate Policy



In 2012, Applied Sciences hosted five speakers in the fourth year of its Climate Policy Speaker Series. The series is designed to assist the NASA community in learning about climate policy from various perspectives, such as economics, national security, and industry. The sessions include discussions about opportunities for Earth observations to inform the climate debate and monitor progress toward policy objectives.

In January, Poornima Madhavan, assistant professor of psychology at Old Dominion University, presented “The Psychology of Climate Change.” She is director of Old Dominion’s Applied Decision Making Laboratory, and she spoke about human decision making under risk, stress, time pressure, and uncertainty. She discussed how these factors affect our attitudes toward climate change, our willingness to change our behavior, and attitudes toward policy on climate change issues.



In April, Dru Crawley, director of building performance products at Bentley Systems, Inc., presented “Impacts of Climate Change and Urbanization on Future Building Performance.” He spoke on the impacts of various energy practices on comfort conditions, building equipment operation, and daily patterns of energy performance. He also spoke on the effects of “heat islands” on climate change, efforts to mitigate these effects by building highly efficient structures, and his perspectives on climate policy.



In May, Juliet Eilperin, national environmental reporter for the *Washington Post*, presented “Climate and the Media.” Eilperin covers science, policy, and politics in areas such as climate change, oceans, and air quality. She provided insights into how a news organization reports on climate and climate policy, including the science and politics of climate change.

In July, Paul Bodnar, a foreign affairs officer in the Office of Global Change at the U.S. Department of State, presented “The State of the International Climate Change Negotiations.” As one of the U.S. negotiators at the Rio+20 Summit in 2012, he described the U.N. climate talks, including some recent successes and failures and some predictions about future international climate policy.

In September, Julia Kumari Drapkin presented “iSeeChange: Crowd-sourced Climate Change Reporting.” She is a public radio reporter and lead producer of iSeeChange, a climate change project at KVNF in western Colorado; iSeeChange is part

of Localore, a nationwide public media experiment produced by the Association of Independents in Radio. She described how her project gathers citizen-generated questions about climate change and poses them to climate scientists. In turning the community questions and the conversations with scientists into reported stories, she described opportunities for the public to learn about climate change's effects on the environment and daily life. She also explained how this media experience had helped scientists better understand citizen-level questions, appreciate the value of citizen observations in the study of climate change, and improve ways to convey their scientific results in different communities.



Applied Sciences will host the speaker series again in 2013. The Program expects to have speakers from the fields of water resources, climate change risk disclosure, insurance, wind energy, and others.

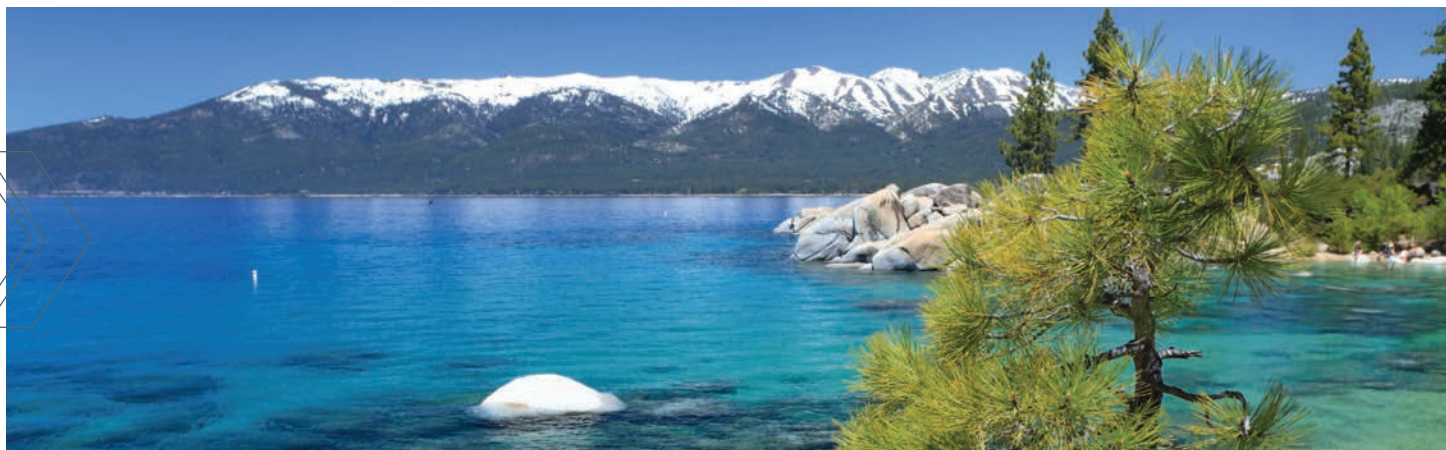


Lake Erie. Terra/MODIS natural-color image, March 21, 2012. A warm winter with more rain than snow created above-average sediment inflows from rivers and streams (tan, muddy water along the shoreline). Milky green, light blue, and white shades may also be sediment-rich water. Some green patches in the water are algae and other phytoplankton due to air temperatures well above normal in the region most of the winter.

To learn more about the series, visit
<http://science.nasa.gov/earth-science/climate-policy-speaker-series>.



Leading International Activities in Earth Science Applications



Applied Sciences continued to be active in international Earth science and applications coordination, especially through the Group on Earth Observations (GEO). With 156 members in 2012, GEO is an intergovernmental organization working to improve the availability, access, and use of Earth observations to benefit society.



GEO is coordinating efforts to establish a Global Earth Observation System of Systems (GEOSS), providing coordinated Earth observations from thousands of ground, airborne, *in situ*, and space-based instruments. GEO focuses on Earth observations for nine Societal Benefit Areas (SBAs): Agriculture, Biodiversity, Climate, Disasters, Ecosystems, Energy, Health, Water, and Weather. To learn more about GEO, visit www.earthobservations.org.

GEO Work Plan

In 2012, GEO began a new 2012–2015 Work Plan. The plan has 26 individual tasks, which are comprised of component activities; there were 60 components in 2012. U.S. representatives were involved in 24 tasks and 41 components, co-leading 34 of them. NASA, especially Applied Sciences, was involved in 17 components. All of the program managers in Applied Sciences were leads or contributors.



Earth Observations Priorities

In 2012, a GEO effort led by Applied Sciences delivered the second edition of a multi-year study of Earth-observing needs common to a variety of users. The report identified the “demand side” of observation needs regardless of current availability, and it ranked key observations that provide critical benefits to society. This edition updated the original report in 2010 to include observation priorities of the Biodiversity SBA with those of the other eight GEO SBAs. The top three priorities remained as precipitation, soil moisture, and surface air temperature.

The priority observations are a baseline for engagement with users on their needs. The results have and can support many activities within GEO, such as an

assessment of the presence of the observations in GEOSS registries or possible investment opportunities.

The report team published an article, “A User-Driven Approach to Determining Critical Earth Observation Priorities for Societal Benefit,” in the December 2012 issue of the *IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing*.

The team also completed work in 2012 on two studies recommended for follow-on activities in the report. The team analyzed the specific, needed observation characteristics for precipitation, as the highest-ranked observation across all nine SBAs. The team also analyzed the availability of the 35 highest-ranked observations. The team expects to issue the reports of these two follow-on studies in 2013. To learn more, visit <http://sbageotask.larc.nasa.gov>.

Health

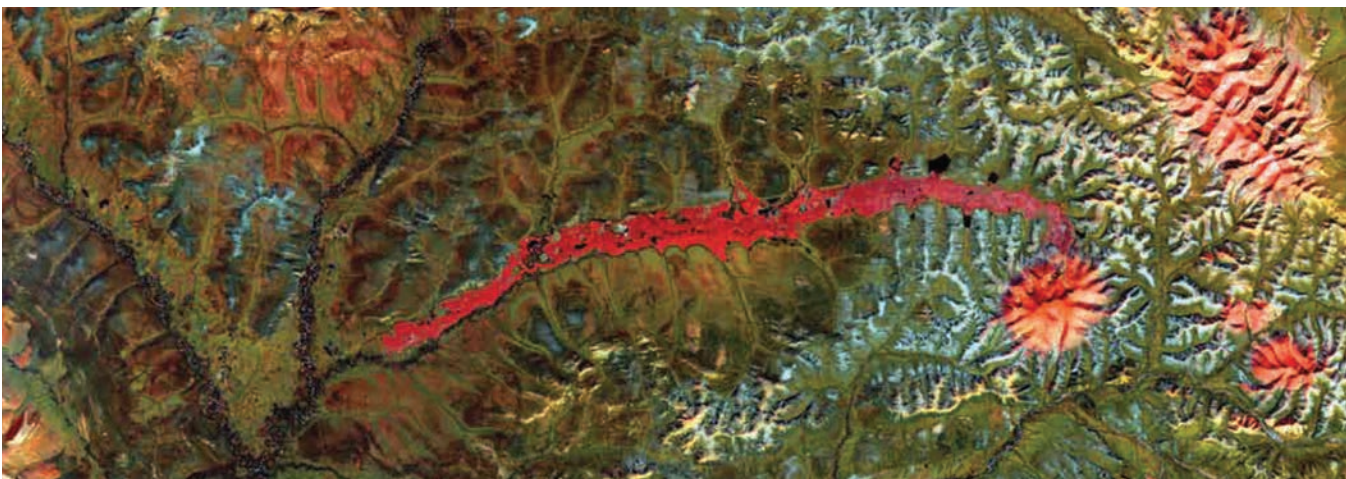
Applied Sciences supports two components in a GEO health task: one on air quality and airborne diseases, and one on vector-borne diseases. For the first, the Program utilized *TRMM*, *MODIS*, and epidemiological data to examine how influenza circulation is affected by meteorological, environmental, or other factors at major population centers around the world through the development of predictive models. In 2012, public health stakeholders (CDC, WHO, ministries of health, and other

national organizations) received the results to strengthen their influenza surveillance and response capabilities. The Program participated in an air quality side event at GEO Plenary IX, highlighting the air quality applications supported by NASA satellites and introducing the new TEMPO mission for diurnal air quality observations.



For the vector-borne component, the Program helped develop an online repository of data for decision making in malaria and meningitis control (see page 50). The Program also partnered with WHO, DoD, and FAO to apply data from Earth-observing sensors to better characterize viral hemorrhagic fever risks (see pages 18–20).

John Haynes, program manager for the Health & Air Quality Applications area, organizes NASA health applications-related contributions to GEO. Haynes and Sue Estes, a Health & Air Quality associate, led NASA's participation in the GEO Health & Environment Community of Practice meeting in 2012.



Anyuyskiy Volcano, Russia.

Earth as Art

“NASA’s Applied Sciences Program has been instrumental in initiating the overarching GEO-GLAM initiative and the crop outlook assessments.”

Joao Soares, GEO Secretariat

GEO-GLAM

The GEO Global Agricultural Monitoring (GEO-GLAM) task seeks to enhance the international community’s capacity to monitor crop production, improve reliability of food supply forecasts, and address potential market disruptions through the use of Earth observations. The goal is to increase food security and market stability worldwide.

The Program continued its support of GEO-GLAM, which made significant progress in 2012. GEO-GLAM worked closely with representatives of CEOS, which is a GEO member, to address space-based observation data needs. In July, representatives of GEO-GLAM and CEOS produced a set of data requirements. In November, NASA hosted a data planning meeting to collect information needed for CEOS to conduct a volumetric analysis of the data required for GEO-GLAM. The primary outcomes of this meeting were the development of a preliminary phased implementation strategy and the translation of the GEO-GLAM requirements into a satellite-based framework. The CEOS Space Data Coordination Group planned to hold a special session on GEO-GLAM at an early 2013 meeting, including discussion of results from the volumetric data analysis.

Chris Justice and Inbal Becker-Reshef at the University of Maryland, College Park, are U.S. leads in the GEO-GLAM task, under Applied Sciences sponsorship. Brad Doorn, program manager for the Water Resources Applications area, organizes NASA contributions to this task.



GEO BON

ESD leadership in the development of the GEO Biodiversity Observation Network (GEO BON) continued in 2012. GEO BON is a global framework for integrating observations from multiple sources to detect and

track changes in biodiversity and ecosystem services, aiding policy development and decisions on improved conservation and natural resource management. ESD is a major sponsor of GEO BON, with Woody Turner and Gary Geller, Ecological Forecasting Applications area program manager and associate, respectively, leading the efforts.

The GEO BON effort made substantial progress in 2012. A key activity was the development of an initial list of Essential Biodiversity Variables (EBVs), facilitated by an experts workshop sponsored and run by Applied Sciences personnel. In December, GEO BON held a meeting in which the working groups confirmed and set targets for completing deliverable products by 2015. The data working group made a major shift in 2012 towards addressing system interoperability. GEO BON developed a plan to more directly meet the needs of the international Convention on Biological Diversity. The GEO BON team completed a paper on EBVs due for publication in *Science* in 2013.



Disasters

Applied Sciences leads a component in a GEO Disasters task and sponsors disaster-related activities under CEOS. In 2012, activities included the ongoing development of flood alert pilots in the Caribbean and Namibia, the articulation of a structure for expanding disaster partnerships among space agencies, and the development of an overall observation strategy to support disaster mitigation. For a CEOS disaster risk management effort, the Program helped create three thematic pilots on floods (led by NASA), seismic hazards, and volcanoes. The NASA team helped author a CEOS floods gap analysis report, which is due for publication in 2013. Francis Lindsay, program manager for Disasters Applications, organizes NASA contributions to the task component.

Agricultural Drought and Water Resources

The Program was part of the organizing committee for the GEO-sponsored workshop, Agricultural Drought and Water Resources, which spanned two GEO SBA task teams. This October 2012 meeting provided an international forum for researchers and managers in agriculture and water resources to discuss recent

advances in understanding the interactions among water use, agricultural drought, agricultural development, and climate change. One session had a special focus on capabilities of drought monitoring and modeling systems as well as assessments of drought effects on agricultural production. Attendees also discussed the design of an



agricultural drought monitoring system in the framework of GEOSS. Among the outcomes, the participants decided to identify data rich sites with irrigated agriculture to assess sensitivity of drought indices in areas of high risk. They also decided to include drought early warning as a goal of the GEO-GLAM task.

Capacity Building

Applied Sciences contributes to a capacity building component in a GEO water task focused on improving the availability of water information. Through SERVIR, NASA contributions to the task included flood forecasting model development and use in Kenya and snow cover mapping in the Himalayan region. In 2012, that overall task developed a GEO water strategy (including capacity building), which the task team reviewed at the AGU Fall Meeting. At the event, NASA provided a summary of NASA activities to support the GEO water strategy as well as 2013 GEO workshops in Africa and Asia. Nancy Searby, program manager for Capacity Building, organizes NASA contributions to this task.



Support of New Urban Applications

The United States and NASA took a leadership role in a new task in the GEO Work Plan in 2012 focused on observations, applications, and modeling of global

urbanization. The task started a global urban supersites initiative to characterize urban ecosystem, population, environmental quality, health, and other issues in support of sustainable urban development. The initiative's initial focus included eight cities: Los Angeles, Atlanta, Mexico City, Athens, Istanbul, San Paolo, Beijing, and Hong Kong. The task established objectives and delivered a plan in 2012. NASA's Dale Quattrochi serves as a U.S. lead for this GEO task.

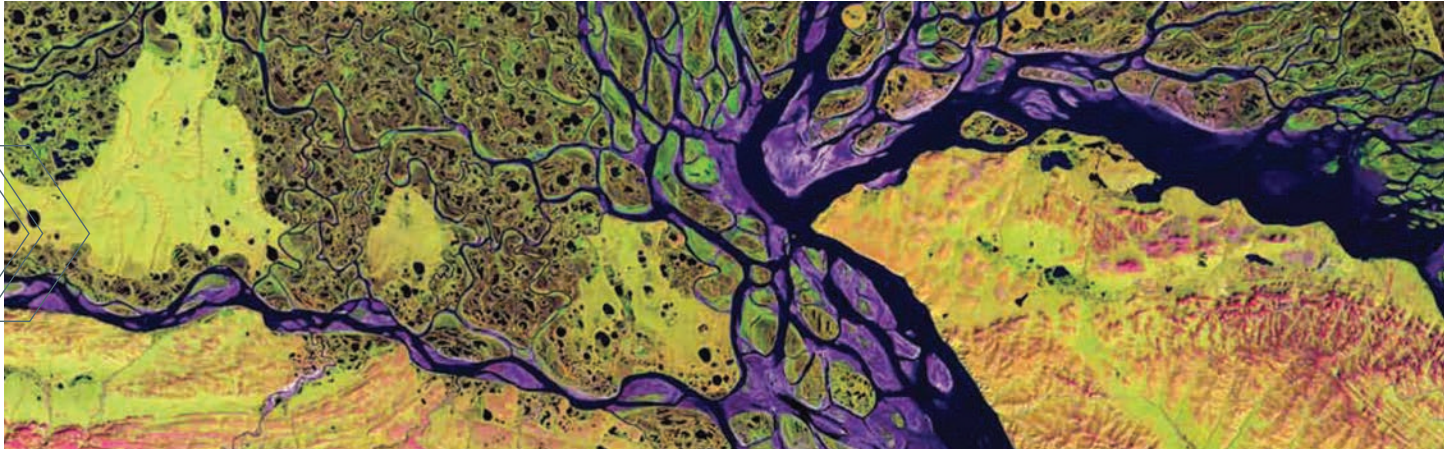


U.S. Group on Earth Observations

The U.S. Group on Earth Observations (USGEO) is an interagency subcommittee of the NSTC Committee on Environment, Natural Resources, and Sustainability (CENRS). Established in 2005, USGEO serves as a forum to lead federal efforts for assessment and coordination of Earth observation activities as well as to formulate U.S. positions and coordinate participation in GEO.

In 2012, CENRS leadership invited NASA ESD to serve as a co-chair of USGEO. NASA ESD accepted the invitation and nominated the director of the Applied Sciences Program, who began as a USGEO co-chair in February.

Reaching New Audiences on Earth

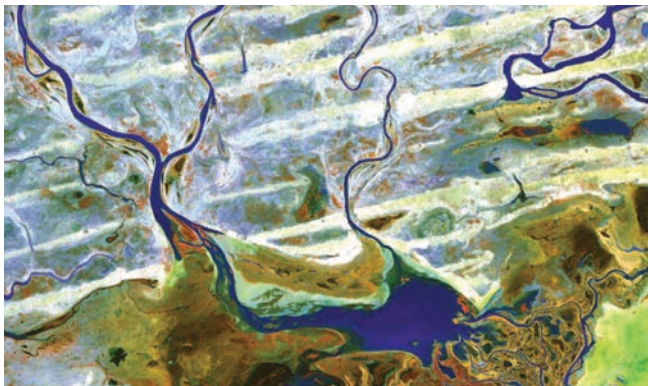


Applied Sciences launched an app and produced a book to showcase stunning satellite images of the Earth to the general public.

In 1960, NASA put its first Earth-observing environmental satellite into orbit around the planet. In 2012, NASA made an app for that.

The Art of Earth Science

Over the decades, Earth-observing satellites have provided invaluable information, and the vantage point of space has provided new perspectives on Earth. NASA has collected countless satellite images of the planet in the pursuit of Earth science research and knowledge.



Niger River, Mali.

Earth as Art

ESD, led by Applied Sciences, compiled 75 images and produced an *Earth as Art* book, e-book, and app for popular audiences. They feature stunning images of Earth from the *Terra*, *Landsat 5*, *Landsat 7*, *EO-1*, and *Aqua* satellites. They celebrate Earth's aesthetic beauty in the patterns, shapes, colors, and textures of the land, oceans, ice, and atmosphere.

.....
The beauty of Earth is clear, and the artistry ranges from the surreal to the sublime.
.....

Sensors on the satellites can measure light outside of the visible range, so the images show more than what is perceptible to the naked eye. The images are intended for viewing enjoyment rather than scientific interpretation.

The Art in Earth

NASA developed the book and app to inform people about their Earth and broaden public awareness of NASA's role in Earth science. Each image has a caption and its location on a global map. The app has a gallery, an interactive directory with images organized by region, the ability to enlarge each scene, and time-lapse images of some locations.

“NASA has released a beautiful book The result is a unique, almost magical look at the planet we call home.”

Kate Bubacz, ABC News

NASA ESD appreciates the cooperation of USGS, the Earth Observatory, and international partners who helped produce the images. All of the people in the public and private sectors who designed the remarkable sensors, operated the robust satellites, and processed the incredible images deserve special recognition and praise.



South Georgia Island, South Atlantic Ocean.

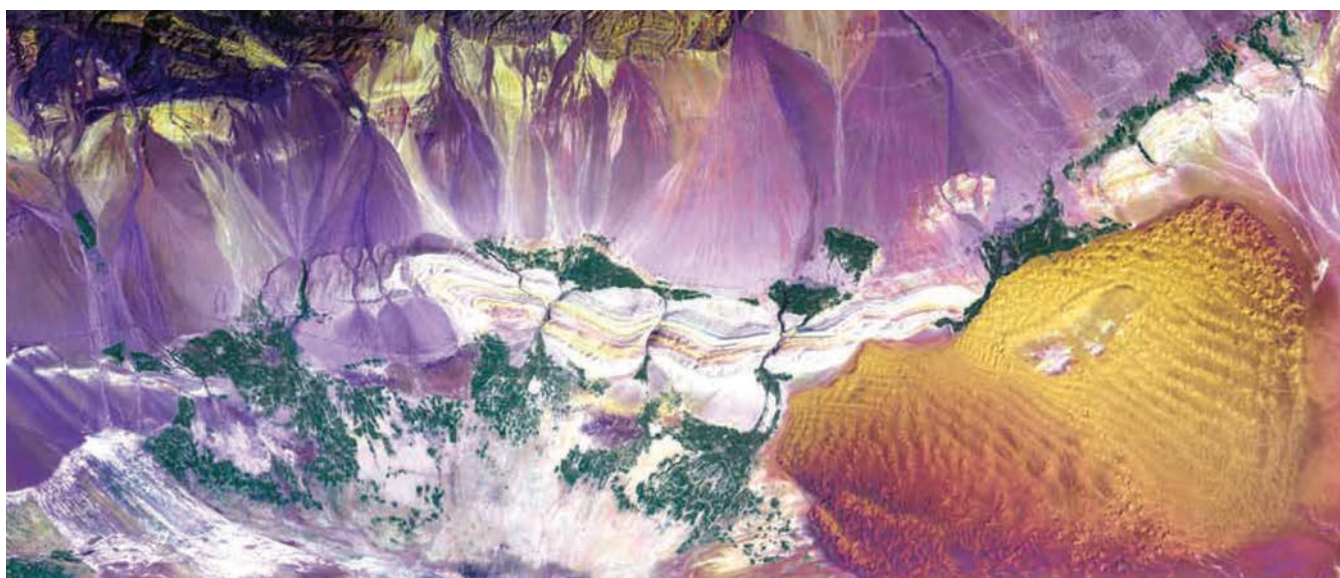
Earth as Art

NASA released the book, e-book, and app in late November 2012, in time to showcase it at the AGU Fall Meeting in early December. ESD director Michael Freilich included *Earth as Art* in the NASA Earth Science Town Hall event at the meeting. Applied Sciences Program director Lawrence Friedl featured *Earth as Art* in the talk he gave at a special Ignite@AGU event.



To learn more about the book, visit www.nasa.gov/connect/ebooks/earth_art_detail.html.

Or search “NASA Earth as Art” in iTunes for the app.



Turpan Depression near the Bogda Mountains, China.

Earth as Art

Looking Ahead



Building on progress this past year, the Applied Sciences Program is enthusiastic for 2013 and beyond. We anticipate the completion of several projects and are eager to initiate new projects, build capacity, and pursue new methods to enable applications of Earth observations.

Applying Earth Observations

Dozens of projects are scheduled to complete in 2013. The applications areas and Capacity Building program will focus on partnership engagement as the projects complete, promoting smooth transitions and sustained uses of Earth observations by the partner organizations.

Applied Sciences will issue solicitations in 2013 for competitively selected projects, including ones in the areas of Health & Air Quality and Water Resources. We will select and initiate feasibility studies for Ecological Forecasting applications. We also will review the results of feasibility studies started in 2012 related to Disasters, Water Resources, and Wildfires applications, selecting a subset of successful studies in each to pursue as full, applications development projects with the partners.

Building Capacity

In January 2013, the Gulf of Mexico Initiative will hold a close-out workshop on 48 projects focused on uses of Earth observations for water management, disaster response, health, aviation safety, ecosystem management, and other issues facing the Gulf region. GOMI will enhance its efforts to extend the results of the projects to state agencies and users throughout the Gulf.

SERVIR, in partnership with USAID, will likely initiate a new hub in Southeast Asia. DEVELOP will expand its participants in its spring and fall terms, and ARSET will further develop its disasters modules and conduct more training sessions.



Socioeconomic Benefits

Early in 2013, the Program will publish a primer on measuring socioeconomic impacts of Earth observations. This primer provides the Earth science community with guidance on language, principles, and techniques used in economic and policy analysis, supporting project teams in communicating the nature and value of their projects.

We will again sponsor an international workshop with the European Commission's Joint Research Center on socioeconomic benefit analysis of Earth observations, and we will continue to conduct impact analyses of our

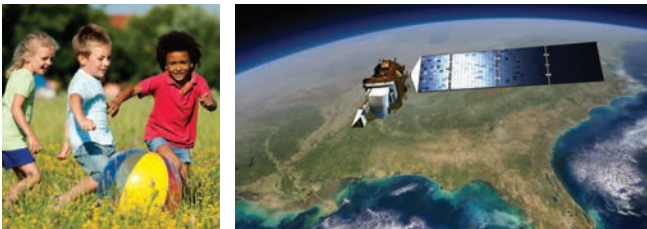
"We appreciate the project teams and our partners for their enthusiasm, innovation, collaboration, and commitment in applying Earth observations to inform decisions and serve society."

Lawrence Friedl, Applied Sciences Program

applications projects. In May 2013, the Geospatial World Forum will focus its annual meeting on the monetization of geospatial values and practices. The Program will participate in a special user forum on societal benefits of environmental and geospatial information, sharing its results and experience in socioeconomic impact analysis.

Applications and Satellite Missions

The *Landsat Data Continuity Mission (LDCM or Landsat 8)* is scheduled to launch in February 2013. This satellite mission continues a 40-year record of global land cover data and significant applications in agriculture, land-use planning, forestry, and water management, among others.



The *Global Precipitation Measurement* mission, scheduled for launch in 2014, plans a workshop in late 2013 to provide the applications community with information on *GPM* data products and prepare this community to use data products soon after launch and validation. The *SMAP* mission will select a third set of early adopters, and *ICESat-2* plans to initiate an early adopters program.

Applied Sciences will support the transition of a NASA airborne, research sensor to the U.S. Forest Service for operational use in wildfire management. The Program will also initiate planning for the next, community-wide *Suomi NPP* applications workshop in 2014.

Review of Satellite Utility

The Program will support NASA's biennial review of Earth-observing satellites past their planned design lifetimes. This Earth Science Senior Review will evaluate 13 NASA satellites. The Program will organize the review's National Interests Panel to assess the utility of the satellites for applied and operational purposes by public- and private-sector organizations. NASA will combine this utility information with scientific value, costs, and technical

performance for each mission in determining which satellites will continue to operate and produce their respective data products.

Program Management

Following the successful model of associate program managers started in 2012, the Program will add two additional associates in 2013—one for interdisciplinary topics in Wildfires and one in Disasters with a geohazards focus. We will also continue bimonthly program reviews to gauge progress in the projects and highlight results.

The Program will complete studies examining the pathways from advances in technology, satellite measurements, and research to practical Earth science applications, assessing key heritage factors contributing to societal benefits.

Overall, we will continue to pursue effective ways to serve as a bridge between the data and knowledge generated by the Earth science community and the information and decision-making needs of organizations. We will continue to help Earth science serve society.

To learn more about the Applied Sciences Program and follow its progress, visit <http://AppliedSciences.NASA.gov>.



Acronyms

AAAS: American Association for the Advancement of Science

AGU: American Geophysical Union

AIRS: Atmospheric Infrared Sounder

AMIS: Agricultural Market Information System

AMS: American Meteorological Society

AQ: Air Quality

AQAST: Air Quality Applied Sciences Team

ARC: Ames Research Center

ARL: Application Readiness Level

ARSET: Applied Remote Sensing Training

ASF: Alaska Satellite Facility

ASHRAE: (formerly) American Society of Heating, Refrigerating and Air-Conditioning Engineers

ASPRS: American Society for Photogrammetry and Remote Sensing

ASTER: Advanced Spaceborne Thermal Emission and Reflection Radiometer

ASTPO: Applied Science and Technology Program Office

AVHRR: Advanced Very High Resolution Radiometer

BOEM: Bureau of Ocean Energy Management

CAL FIRE: California Department of Forestry and Fire Protection

CASI: Climate Adaptation Science Investigators

CCIEA: California Current Integrated Ecosystem Assessment

CDC: Centers for Disease Control and Prevention

CDWR: California Department of Water Resources

CENRS: Committee on Environment, Natural Resources, and Sustainability

CEOS: Committee on Earth Observation Satellites

CMIP5: Coupled Model Intercomparison Project Phase 5

COASTER: Customized Online Aggregation & Summarization Tool for Environmental Rasters

CREST: Coupled Routing and Excess Storage

CYGNSS: Cyclone Global Navigation Satellite System

DFRC: Dryden Flight Research Center

DHS: Department of Homeland Security

DISCOVER-AQ: Deriving Information on Surface conditions from Column and Vertically Resolved Observations Relevant to Air Quality

DoD: Department of Defense

DOE: Department of Energy

DRI: Desert Research Institute

DSSAT: Decision Support System for Agrotechnology Transfer

EAGLES: Ecosystem Assessment, Geospatial analysis, and Landscape Evaluation System

EBV: Essential Biodiversity Variable

E-DECIDER: Earthquake Data Enhanced Cyber-Infrastructure for Disaster Evaluation and Response

EIS: environmental impact statement

ENTRO: Eastern Nile Technical Regional Office

EO-1: Earth Observing-1

EOS: Earth Observing System

EPA: Environmental Protection Agency

ESA: European Space Agency

ESD: Earth Science Division

ESIP: Federation of Earth Science Information Partners

EU: European Union

EV: Earth Venture

FAO: Food and Agriculture Organization of the United Nations

FAS: Foreign Agricultural Service

FEMA: Federal Emergency Management Agency

FIA: Forest Inventory and Analysis

FLC: Federal Laboratory Consortium for Technology Transfer

ForCaMF: Forest Carbon Management Framework

FY: fiscal year

GEO BON: GEO Biodiversity Observation Network

GEO: Group on Earth Observations

GEO-GLAM: GEO Global Agricultural Monitoring

GEOS-5: Goddard Earth Observing System Model, Version 5

GEOSS: Global Earth Observation System of Systems

GIS: geographic information

system

GISS: Goddard Institute for Space Studies

GOES: Geostationary Operational Environmental Satellite

GOMA: Gulf of Mexico Alliance

GOMI: Gulf of Mexico Initiative

GPM: Global Precipitation Measurement

GPS: Global Positioning System

GRACE: Gravity Recovery and Climate Experiment

GRACE-FO: GRACE Follow-On

GRC: Glenn Research Center

GRIDSSAT: Gridded DSSAT

GSFC: Goddard Space Flight Center

HYCOM: HYbrid Coordinate Ocean Model

HyspIRI: Hyperspectral Infrared Imager

IATTC: Inter-American Tropical Tuna Commission

ICESat-2: Ice, Cloud, and land Elevation Satellite-2

ICIMOD: International Center for Integrated Mountain Development

IEEE: Institute of Electrical and Electronics Engineers

IISD: International Institute for Sustainable Development

IPCC: Intergovernmental Panel on Climate Change

IRI: International Research Institute for Climate and Society

ISERV: ISS SERVIR Environmental Research and Visualization System

ISPRS: International Society for Photogrammetry and Remote

Sensing

ISS: International Space Station

JAXA: Japan Aerospace
Exploration Agency

JPL: Jet Propulsion Laboratory

JRC: Joint Research Center

JSC: Johnson Space Center

KML: Keyhole Markup Language

KSC: Kennedy Space Center

LADCO: Lake Michigan Air
Directors Consortium

LANCE: Land Atmosphere Near
real-time Capability for EOS

LaRC: Langley Research Center

LDAS: Land Data Assimilation
System

LDCM: Landsat Data Continuity
Mission

LiDAR: Light Detection And
Ranging

LIS: Land Information System

MBARI: Monterey Bay Aquarium
Research Institute

MERRA: Modern-Era
Retrospective analysis for
Research and Applications

MGET: Marine Geospatial
Ecology Tools

MIT: Massachusetts Institute of
Technology

MODIS: Moderate Resolution
Imaging Spectroradiometer

MSFC: Marshall Space Flight
Center

MTSAT: Multifunctional
Transport Satellite

MyCOE: My Community Our
Earth

NASA: National Aeronautics and
Space Administration

NCA: National Climate
Assessment

NCAR: National Center for
Atmospheric Research

NDMC: National Drought
Mitigation Center

NDVI: Normalized Difference
Vegetation Index

NFS: National Forest System

NIH: National Institutes of Health

NLDAS: North American Land
Data Assimilation System

NLDAS-2: North American Land
Data Assimilation System
(Phase 2)

NMFS: National Marine Fisheries
Service

NOAA: National Oceanic and
Atmospheric Administration

NPP: National Polar-orbiting
Partnership

NREL: National Renewable
Energy Laboratory

NRL: Naval Research Laboratory

NSIDC: National Snow and Ice
Data Center

NSTC: National Science and
Technology Council

NYCDEP: New York City
Department of Environmental
Protection

OCO-2: Orbiting Carbon
Observatory-2

OECD: Organization for
Economic Cooperation and
Development

OMB: Office of Management and
Budget

OMI: Ozone Monitoring
Instrument

OSI: Office of Strategic

Infrastructure

OSTM: Ocean Surface
Topography Mission

PFMC: Pacific Fishery
Management Council

PHAM: Pelagic Habitat Analysis
Module

PM2.5: fine particulate matter

QuikSCAT: Quick Scatterometer

REGARDS: REasons for
Geographic And Racial
Differences in Stroke

RFF: Resources for the Future

ROI: return on investment

RSS: Rich Site Summary

SAR: Synthetic Aperture Radar

SBA: Societal Benefit Area

SDSS: Spatial Decision Support
System

SEAS: *Sargassum* Early Advisory
System

SeaWiFS: Sea-viewing Wide
Field-of-view Sensor

SMAP: Soil Moisture Active
Passive

SMD: Science Mission
Directorate

SMOS: Soil Moisture and Ocean
Salinity

SPoRT: Short-term Prediction
Research and Transition

SRTM: Shuttle Radar
Topography Mission

SSC: Stennis Space Center

SST: sea surface temperature

SVS: Scientific Visualization
Studio

SWE: snow water equivalent

SWOT: Surface Water Ocean
Topography

TEMPO: Tropospheric Emissions:
Monitoring of Pollution

TOPS: Terrestrial Observation
and Prediction System

TRMM: Tropical Rainfall
Measuring Mission

UAB: University of Alabama at
Birmingham

UAVSAR: Uninhabited Aerial
Vehicle Synthetic Aperture Radar

UICDS: Unified Incident
Command and Decision Support

URISA: Urban and Regional
Information Systems Association

USACE: United States Army
Corps of Engineers

USAID: United States Agency for
International Development

USDA: United States Department
of Agriculture

USFS: United States Forest
Service

USFWS: United States Fish and
Wildlife Service

USGCRP: United States Global
Change Research Program

USGS: United States Geological
Survey

USWP: United States Water
Partnership

VIIRS: Visible Infrared Imaging
Radiometer Suite

WFF: Wallops Flight Facility

WHO: World Health Organization

WONDER: Wide-ranging Online
Data for Epidemiologic Research

WRF: Weather Research and
Forecasting

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